Low-Cost Options for Moderate Levels of Mercury Control

Topical Report for
Entergy's Independence Station, Unit 2
Reporting Period: January 1, 2005–June 30, 2007

Principal Author: Sharon Sjostrom

Submitted: May 2008

DOE Award Number DE-FC26-05NT42307
Report Number 42307R15

ADA-ES, Inc.
8100 SouthPark Way, Unit B
Littleton, Colorado 80120
(303) 797-8729

DISCLAIMER

ACKNOWLEDGMENTS

This project was made possible through the generous funding of the Department of Energy's National Energy Technology Laboratory and industry partners including ADA-ES, Inc., Entergy, EPRI, Alliant, ATCO Power, DTE Energy, Oglethorpe Power, NORIT Americas Inc., Xcel Energy, Southern Company, Arch Coal, and EPCOR.

Andrew O'Palko was the project manager for DOE/NETL. David Muggli was the initial ADA-ES project manager for testing at Independence Station until 4Q06. Starting in 4Q06, Sharon Sjostrom was the Project Manager. Tom Campbell was the project engineer responsible for all site activities throughout the test program. The team gratefully acknowledges the efforts and support of Richard Roberts (Entergy Technical Support), Mike Rees (Engineer), Todd Bradberry (Engineer), Steve Coker (Sr. Engineer), Kellee Fletcher (Environmental Specialist), Joe Hantz (Fossil Environmental Support), and the staff at Independence Station. Ramsay Chang was a key technical advisor and provided project management for EPRI. Connie Senior at Reaction Engineering International provided technical support and coordinated the CFD modeling efforts conducted by REI. The ADA-ES test team included Brian Donnelly, Cody Wilson, Chad Sapp, Erik Zipp, Brandon Hagen, and Martin Dillon from ADA-ES. Mike Durham, Jean Bustard, Cam Martin, and Travis Starns from ADA-ES provided key technical input into the project. Richard Schlager managed the contracts. Anne Sjostrom and Andrea Adams assisted with the technical writing, and Cindy Larson edited and assembled all technical reports.

ABSTRACT

On March 15, 2005, EPA issued the Clean Air Mercury Rule (CAMR) (subsequently vacated in February 2008), which required phased-in reductions of mercury emissions from electric power generators. ADA-ES, Inc., with support from DOE/NETL and industry partners, conducted evaluations of EPRI's TOXECON II™ process and of high-temperature reagents to determine the capabilities of sorbent/reagent injection, including activated carbon, for mercury control on different coals and air emissions control equipment configurations in accordance with the existing CAMR regulations.

This is the final site report for TOXECON II™ tests conducted at Entergy's Independence Steam Electric Station (ISES), one of two sites evaluated in this DOE/NETL program. The other site in the program is MidAmerican's Louisa Station, where high-temperature reagent testing was conducted. This project was funded through the DOE/NETL Innovations for Existing Plants program. It was a Phase II project with the goal to develop mercury control technologies that can achieve 50–70% mercury capture at costs 25–50% less than baseline estimates of \$50,000–\$70,000/lb of mercury removed. Results from testing at Independence indicate that the DOE goal was successfully achieved. Further improvements in the process are recommended, however.

Independence typically burns Powder River Basin (PRB) coal in its 880-MW Unit 2. Various sorbent injection tests were conducted on 1/8 to 1/32 of the flue gas stream either within or in front of one of the four ESP boxes (SCA = 542 ft^2/kacfm). Initial mercury control evaluations indicated that, although significant mercury control could be achieved by using the TOXECON II™ design, the sorbent concentration required was higher than expected, possibly due to poor sorbent distribution. Subsequently, the original injection grid design was modeled and the results revealed that the sorbent distribution pattern was determined by the grid design, fluctuations in flue gas flow rates, and the structure of the ESP box. To improve sorbent distribution, the injection grid and delivery system was redesigned and its effectiveness evaluated. The results are summarized along with the impacts of the TOXECON II™ process on ESP operation and particulate emissions.

TABLE OF CONTENTS

INTRODUCTION 1

EXECUTIVE SUMMARY 2

DESCRIPTION OF OVERALL PROGRAM 4

INDEPENDENCE PROJECT OBJECTIVES AND TECHNICAL APPROACH 7

- Importance of Testing at Independence 8
- Independence Site Description 9
  - General Description of Unit 2 9
  - Sorbent Injection and Monitoring Locations 13
- Equipment Descriptions 16
  - Sorbent Delivery Systems 16
  - TOXECON II™ Injection System 19
  - Mercury Monitoring System 22
  - Sorbent Trap Equipment and Analysis 23
  - Particulate Monitors 24
  - In-Situ Fly Ash Sampling Device 24
- Description of Field Testing Subtasks 25
  - Sorbent Selection and Description 28
  - Sample and Data Coordination 28
  - Baseline Testing (No Sorbent Injection) 29
  - Parametric Testing 30
  - Long-Term Testing 31
  - Ash Recycle Testing 33

RESULTS FROM INDEPENDENCE TESTING 34

- Velocity and Temperature Profiles 34
- Baseline Mercury Removal 38
- Parametric Mercury Removal 41
  - Stage I 41
  - Stage II 44
  - Stage III 47
- Long-Term Mercury Removal 48
  - Original Grid: 30-Day Continuous Injection 48
- Long-Term Speciation Results 55
- Long-Term and Parametric Comparison 56
  - Long-Term Operational Demonstration 58
  - Extended Test with Redesigned Grid 61
- Ash/Carbon Recycle Test Results 63

Modeling Results ... 66
CFD Modeling of Grid and ESP ... 67
Physical Modeling of ESP B-box ... 69
Physical Modeling of Injection Grid ... 70
Characterization of Process Solids and Liquids ... 75
Coal Analysis ... 75
Carbon and Mercury in Ash ... 76
Leaching Stability (Hg, Other Metals, and Halogens) ... 83
Balance-of-Plant-Impacts ... 85
ESP Operation and Particulate Emissions ... 85
Baseline ESP Performance ... 85
Parametric ESP Performance ... 90
Long-Term ESP Performance ... 109
Redesigned Grid ... 122
Manual Particulate Measurements ... 127
Ash Sales ... 128
Results of Halide Measurements ... 130
Effect of DARCO® Hg-LH on Halide Emissions ... 130

ECONOMIC ANALYSIS ... 131

System Description ... 132
Balance-of-Plant Requirements ... 133
Cost and Economic Methodology ... 133
Capital Costs ... 134
Operating and Levelized Costs ... 134

CONCLUSIONS ... 136

REFERENCES ... 138

LIST OF ACRONYMS AND ABBREVIATIONS ... 139

APPENDIX A: Independence Test Plans ... 140

APPENDIX A1: Entergy Independence Test Plan—September 15, 2005 ... 141
APPENDIX A2: Follow-On Test Plan—February 23, 2006 ... 170
APPENDIX A3: Independence Test Plan—December 29, 2006 ... 174
APPENDIX A4: Extended Test Matrix ... 188

APPENDIX B: Equipment Descriptions ... 191

APPENDIX C: Field Test Logs ... 194

APPENDIX C1: Independence Test Log—November 15, 2005 ... 195
APPENDIX C2: EPRI Extended Test Log—March 11, 2006 ... 214
APPENDIX C3: Independence Log Sheet—March 8, 2007 ... 231

APPENDIX D: Source Testing **257**

APPENDIX D1: Source Testing—August 15–18, 2005 258
APPENDIX D2: Source Testing—October 17–19, 2005 542
APPENDIX D3: Source Testing—October 24–26, 2005 659
APPENDIX D4: Source Testing—November 1–2, 2005 948
APPENDIX D5: Source Testing—January 29–February 2, 2007 1058

APPENDIX E: Consulting Reports **1177**

APPENDIX E1: REI, Lance Modeling—May 31, 2006 1178
APPENDIX E2: REI, Lance Modeling—August 11, 2006 1198
APPENDIX E3: REI, Lance Modeling—September 14, 2006 1221
APPENDIX E4: NELS, ESP Flow Modeling—December 2006 1231

APPENDIX F: Sample Collection and Management Plan **1301**

LIST OF TABLES

Table 1. Host site key descriptive information. 5
Table 2. Field-testing schedule. 5
Table 3. Independence Unit 2 key operating parameters. 10
Table 4. Field-test sequence at Independence. 26
Table 5. Data collected during field-testing at Independence Unit 2. 29
Table 6. Comparison of ESP B-box outlet Hg levels obtained by different methods during 2005 Baseline OH runs. 38
Table 7. Average total vapor-phase mercury across the ESP B-box during 2007 Baseline testing. Values corrected to 3% O_2. 41
Table 8. Average total vapor-phase mercury removal efficiency during 2005 Long-Term testing. 54
Table 9. Mercury levels across ESP B-box obtained by different methods during injection of 5 lb/MMacf DARCO® Hg-LH in the rear-box location. (OH is Hg^{2+} + Hg^0; S-CEM is total vapor-phase mercury; all values given in μg/dNm^3 and corrected to 3% O_2.) 54
Table 10. Hg levels across ESP B-box obtained by different methods during injection of 5 lb/MMacf DARCO® Hg-LH in the mid-box location. (OH is Hg^{2+} + Hg^0; S-CEM and STM are total vapor-phase mercury; all values given in μg/dNm^3 and corrected to 3% O_2.) 55
Table 11. Hg levels across ESP B-box obtained by different methods during injection of 5 lb/MMacf DARCO® Hg-LH in the mid-box location. ColoWyo coal burned. (OH is Hg^{2+} + Hg^0; S-CEM and STM are total vapor-phase mercury; all values given in μg/dNm^3 and corrected to 3% O_2.) NB: Run 2 was aborted. 55
Table 12. Results from Baseline and Long-Term coal analyses (dry basis). 76
Table 13. SGLP results from Independence (mg/L) during Long-Term testing while injecting mid-ESP. 84
Table 14. Percent of "Total in Sample" element concentration leaching from ash sample. 84
Table 15. TCLP results from Independence (mg/L). 84
Table 16. Average CPM values at ESP B outlet duct on the Test and Control Sides during September 2005 Baseline testing. 87
Table 17. EPA Method 17 results for Unit 2 during Baseline testing August 17–18, 2005. 88
Table 18. Test-side ESP B average power levels during Baseline testing. 89
Table 19. Average (6-minute) stack opacity (%) during 2005 Parametric testing. One-eighth of flue gas stream was treated when PAC was injected either in the mid(dle) or rear of the test side of ESP-B-box during high (> 750 MW) boiler load. 106

Table 20. Average CPM values on test and control sides of ESP B-box during October 2005 Parametric testing. One-eighth of flue gas stream was treated when PAC was injected in the rear of the test side of ESP B-box during high (> 750 MW) boiler load. 106
Table 21. Average (6-minute) stack opacity during 2005 Long-Term testing. (See caption for Figure 78 for description of ACI conditions.) 115
Table 22. Average CPM values at the test outlet duct of ESP B-box during 2005 Long-Term testing. (See caption for Figure 78 for explanation of sorbent injection conditions.) 116
Table 23. Method 17 results for Unit 2 during 2005 Long-Term testing. 119
Table 24. Baseline PM measurements – stack. 122
Table 25. PAC injection with redesigned grid PM measurements – stack. 123
Table 26. B-west ESP east (no PAC) outlet PM measurements. 125
Table 27. B-west ESP west (PAC–redesigned injection grid) outlet PM measurements. 125
Table 28. 2005 Baseline/injection PM testing. 127
Table 29. 2007 Method 5 PM Measurements. 128
Table 30. Size distribution of ash collected in first two fields. 129
Table 31. Average values of Method 26A runs at ESP B-box. 130
Table 32. System design criteria for mercury control at Independence Unit 2. 5 lb/MMacf injection, > 90% mercury control. 131
Table 33. Summary of mercury removal efficiencies and costs for different APC configurations, coals, and sorbents. 132
Table 34. Capital and operating and maintenance cost estimate summary for ACI system on Independence Unit 2. Annual basis 2007. 134
Table 35. Levelized costs summary. 135

LIST OF FIGURES

Figure 1. TOXECON II™ general arrangement. ... 8
Figure 2. ESP electrical field and ash hopper configuration and numbering scheme. ... 11
Figure 3. Line schematic of one-half of the Unit 2 flue gas flow. ... 12
Figure 4. Photo of north ESP B/D outlet duct–Unit 2. ... 12
Figure 5. Photo of NELS 1/12 scale model. One-half of one Unit 2 ESP box. (Third field plates removed in photo.) ... 12
Figure 6. Plan view sketch of electrical fields for ESP B-box showing sorbent injection grid locations. ... 14
Figure 7. ESP B test side inlet duct access port configuration; plan view (top) and elevation view (bottom). Port 5 was blocked. ... 15
Figure 8. Elevation sketch of ESP B-box at Independence Unit 2. Indicates injection and monitoring locations for the west half of the box. ... 16
Figure 9. Porta-PAC™ and carbon injection storage silo and feeder trains at the Independence test site. ... 17
Figure 10. Upgraded blower system used in 2007. ... 18
Figure 11. Schematic of injection grid. ... 20
Figure 12. Injection grid between ESP fields. ... 21
Figure 13. Redesigned multi-port lance. ... 22
Figure 14. Sketch of mercury measurement system. ... 23
Figure 15. In-situ fly ash sampling device. ... 25
Figure 16. ESP duct velocity profile expressed as Percentage of Average Velocity (Vav). (a) Inlet: Baseline 2005. (Velocity values at Ports 9 and 5 are interpolated.) (b) Inlet: Long-Term 2005. (Velocity values at Ports 9 and 5 are interpolated.) (c) Outlet: Baseline 2005. (Velocity values at Ports 4–6 and Port 9 are interpolated.) (d) Outlet: Long-Term 2005. (Velocity values for Ports 5–8 are interpolated.) ... 35
Figure 17. ESP duct temperature profile. ... 37
Figure 18. Average 30-minute total vapor-phase mercury concentrations for 2005 pre-Baseline and Baseline test period. ... 39
Figure 19. Average total mercury at the inlet and outlet of the ESP B-box during 2005 Baseline testing. ... 39
Figure 20. Fraction of elemental mercury across the ESP B-box during 2005 Baseline testing. ... 40
Figure 21. Trend plot of average total vapor-phase mercury across the ESP B-box during 2007 Baseline tests. Values corrected to 3% O_2. ... 41
Figure 22. Comparison of sorbent performance during the first stage of Parametric tests. Midbox injection, field B-7 down, field B-3 low/no power. Dashed line at 70%. ... 42
Figure 23. Average percentage of elemental mercury across the test side of ESP B during the first stage of Parametric tests (August 2005). ESP field B-7 non-operational; mid-box injection. ... 43

Figure 24. Average mercury removal efficiency for test sorbents at various injection concentrations across the test side and control side of ESP B-box during the second stage of Parametric tests (October 2005). ESP field B-7 operational; rear box injection. 45
Figure 25. Average mercury removal efficiency for test sorbent DARCO® Hg-LH at single injection concentration across the test side and control side of ESP B-box during the second stage of Parametric tests (October 2005). ESP field B-7 operational; dual injection to both mid and rear box. 46
Figure 26. Mercury removal efficiency of Hg-LH during 2007 Parametric tests and using redesigned lances.................. 48
Figure 27. Mercury removal trends during Long-Term testing: October–November 2005. (Hg levels corrected to 3% O_2.) 50
Figure 28. Average total vapor-phase mercury removal efficiency during DARCO® Hg-LH injection upstream of the final field. 52
Figure 29. Average total vapor-phase mercury removal efficiency during DARCO® Hg-LH injection upstream of the middle collection field. 53
Figure 30. Comparison of mercury speciation across the ESP B-box at the mid-box injection location with 5 lb/MMacf of sorbent under high (> 750 MW) and low (< 450 MW) boiler load conditions that overlapped times when Ontario Hydro tests were conducted during Long-Term testing 2005. 56
Figure 31. Comparison of DARCO® Hg and Hg-LH performance from Parametric and Long-Term (LT) tests at the mid-ESP (F5) and rear-ESP (F7) injection locations. 57
Figure 32. Box-whisker plots of the 30-minute averages of mercury removal efficiency at high (> 750 MW) and low (< 450 MW) boiler loads when 4–5.5 lb/MMacf of DARCO® Hg-LH was injected mid-box and the middle field (B5) was on or off. 59
Figure 33. Total vapor-phase mercury at various locations in the test side of ESP B-box when 5.5 lb/MMacf of DARCO® Hg-LH was injected mid-box during high (> 750 MW) boiler load on December 13, 2005. Data for outlet ports 4, 7, and 10 are STM results. Concurrent S-CEM readings at the inlet and outlet are shown for reference with the corresponding port location denoted as either P9 (inlet port 9) or P8 (outlet port 8). Values corrected to 3% O_2. 60
Figure 34. Box-whisker plots of mercury removal efficiency across the ESP when DARCO® Hg-LH was injected at the inlet of the ESP at various injection concentrations. 61
Figure 35. Mercury removal comparison of injection location and grid design. 62
Figure 36. Mercury removal comparison of injection location and grid design. 63
Figure 37. Box-whisker plots of the mercury removal efficiency across the ESP during the Ash Recycling tests. 65

Figure 38. Plot of total vapor-phase mercury at ESP B 23 inches into outlet duct at port 9 and 50 inches into outlet duct at port 8. Also included is the boiler load and approximate concentration of carbon injected into the inlet duct of the ESP during the ash recycle test (November 14, 2005). 66
Figure 39. CFD model of average carbon distribution from nozzles along the length of an injection lance as well as from one-half of the injection grid system.......... 67
Figure 40. CFD model results of carbon particle distribution in the middle of the ESP.. 68
Figure 41. CFD model results of carbon particle distribution in the rear of the ESP. 68
Figure 42. NELS physical modeling of plume penetration.. 69
Figure 43. NELS physical modeling of ESP B B-7 outlet field exit.................................... 70
Figure 44. Carbon penetration at high load using the original grid design. 71
Figure 45. Carbon penetration at low load using the original grid design. 72
Figure 46. Carbon penetration at high load using the redesigned injection grid system. 72
Figure 47. Physical model of carbon distribution from original lance.................................. 73
Figure 48. Physical model of carbon distribution from redesigned lance arrangement......... 74
Figure 49. Baseline Mercury and LOI of fly ash samples collected from B-ESP hoppers on Test and Control (Ctrl) sides of the ESP during 2005 testing. 79
Figure 50. Mercury and LOI in hopper ash samples collected during Baseline testing......... 80
Figure 51. Long-term Mercury and LOI of fly ash samples collected from B-ESP fields on Test and Control (Ctrl) sides during 2005 testing when Colo Wyo was burned. DARCO® Hg-LH was injected either mid-box (i.e., between the 2nd and 3rd set of fields on the Test side) or rear-box (i.e., between the 3rd and 4th set).. 81
Figure 52. Mercury normalized to carbon content for hopper ash samples collected during Baseline testing... 82
Figure 53. ESP operation and (6-minute) opacity during August and September 2005 Baseline testing. Opacity represents stack data. 86
Figure 54. (a) Box whisker plots of stack opacity (6-minute) percentages during Baseline 2005 testing when B-F7 was non-operational (F7n, August)) and operational (F7o, September) at boiler loads > 750 MW (hi) and < 450 MW (lo). Also shown are peak 10-second opacity (10secP) percentages for the same conditions. (b) The same data shown as averages........................... 87
Figure 55. Box-whisker plots of power in ESP B-box rear electrical fields during August and September 2005 Baseline Testing. F5 and F6 are the third fields on the test and control sides, respectively; F7 and F8 are the last fields on the test and control sides, respectively. Plot contrasts power levels when boiler load is > 750 MW (hi) and < 450 MW (lo). 89
Figure 56. Average Spark Rate in ESP B-box electrical fields during 2005 Baseline testing. F5 and F6 are the third fields on the test and control sides, respectively; F7 and F8 are the last fields on the test and control sides, respectively. Plot contrasts overall spark rates with those when boiler load is at high loads (> 750 MW) and low load (< 450 MW). 90

Figure 57. Operating trends during DARCO® Hg injection upstream of field 5. 91
Figure 58. Operating trends during DARCO® Hg-LH injection upstream of field 5. 92
Figure 59. Operating trends during DARCO® E10 injection upstream of field 5. 93
Figure 60. Operating trends during DARCO® E11 injection upstream of field 5. 94
Figure 61. Operating trends during DARCO® Hg-LH injection upstream of field 5. 95
Figure 62. Operating trends during DARCO® Hg injection upstream of field 5. 96
Figure 63. Operating trends during DARCO® E10 injection upstream of field 7. 97
Figure 64. Operating trends during DARCO® E11 injection upstream of field 7. 98
Figure 65. Operating trends during DARCO® Hg injection upstream of field 7. 99
Figure 66. Operating trends during DARCO® Hg injection upstream of field 7. 100
Figure 67. Operating trends during DARCO® Hg-LH injection upstream of field 7. 101
Figure 68. Operating trends during DARCO® Hg-LH injection upstream of field 7. 102
Figure 69. Operating trends during DARCO® Hg-LH injection upstream of fields 5 (first period) and 7 (second period). 103
Figure 70. Operating trends during DARCO® Hg-LH injection upstream of fields 5 and 7. 104
Figure 71. Box whisker plots of (6-minute) stack opacity during 2005 Parametric testing. One-eighth of flue gas stream was treated when PAC was injected either in the mid(dle) or rear of the test side of ESP-B-box during high (> 750 MW) boiler load. 105
Figure 72. Box-whisker plots of power in ESP B-box rear electrical fields during 2005 Parametric tests. F5 and F6 are the third pair of fields on the test and control sides, respectively; F7 and F8 are the fourth fields on the test and control sides, respectively. One-eighth of flue gas stream was treated when PAC was injected either between F3 and F5 (8/05) or between F5 and F7 (10/05) of the ESP B-box during high (> 750 MW) boiler load............ 107
Figure 73. Average spark rates for the ESP B-box last two pairs of electrical fields during 2005 Parametric tests. F5 and F6 are the third pair of fields on the test and control sides, respectively; F7 and F8 are the fourth fields on the test and control sides, respectively. One-eighth of flue gas stream was treated when PAC was injected either directly upstream of F5 (8/05) or directly upstream of F7 (10/05) of the ESP B-box during high (> 750 MW) boiler load. 108
Figure 74. ESP Operation and (6-minute) opacity during October and November 2005 Long-Term testing. Opacity represents stack data. One-eighth of flue gas stream was treated when PAC was injected in the test side of ESP-B. 110
Figure 75. Box whisker plots of power in the two rear electrical fields on the test side of ESP B-box during 2005 Long-Term testing. (See caption for Figure 78 for explanation of sorbent injection conditions.) 112
Figure 76. Average spark rate in ESP B-box electrical fields during 2005 Long-Term testing. F5 and F6 are the third fields on the test and control sides, respectively; F7 and F8 are the last fields on the test and control sides, respectively. Plot contrasts overall spark rates with those when boiler load

is at high loads (> 750 MW) and low load (< 450 MW). (See caption for Figure 78 for description of ACI conditions.) 113
Figure 77. ESP Operation and (6-minute) opacity during shifts in CE rapper B-F7 rap duration and frequency. The vertical dashed line in the left charts indicates the shift in rap duration from 140 seconds to 70 second once per hour. The vertical dashed line in the right charts indicates the shift in rap duration back to 140 seconds accompanied by a decrease in frequency to every two hours. 114
Figure 78. Box whisker plots of (6-minute) stack opacity during 2005 Long-Term testing. One-eighth of flue gas stream was treated when PAC was injected either in the mid(dle) or rear of the test side of ESP B-box during hi (> 750 MW) and lo (< 450 MW) boiler loads. Rear injection included three different rapper protocols for field B-F7: (1) duration of 140 seconds once per hour (D:140,F:1), (2) duration of 70 seconds once per hour (D:70,F:1), and (3) duration of 140 seconds once every 2 hours. Also shown is the 10-second peak opacity value for the same conditions. During the mid injection phase, coal from the ColoWyo mine was burned in place of the typical PRB coal during two short periods. 115
Figure 79. Box whisker plots of CPM values at the test and control outlet ducts of ESP B-box during 2005 Long-Term testing. (See caption for Figure 78 for explanation of sorbent injection conditions.) 116
Figure 80. ESP operation and (6-minute) stack opacity during shifts in PAC injection location. The vertical dashed line in the left charts indicates the shift from injecting between ESP B-box F5 and F7 (rear-box) to between F3 and F5 (mid-box). The first vertical dashed line in the right charts indicates shift from mid-box to rear-box injection and the second line indicates the shift back to mid-box injection. 118
Figure 81. ESP Operation and (6-minute) stack opacity during days when M17 (October 25–26, 2005) and Ontario Hydro (both October 25–26 and November 1–2, 2005) tests were conducted while sorbent was injected into 1/8 of the flue gas stream in ESP B-box between fields F3 and F5 (mid-box). 119
Figure 82. ESP Operation and (6-minute) stack opacity during a temporary increase in sorbent concentration (left charts) and while rear fields of the test side of ESP B were temporarily removed from the POS (right charts). 121
Figure 83. Opacity and ESP power trends with and without PAC injection (redesigned injection grid). 123
Figure 84. Opacity and ESP power trends with and without PAC injection (redesigned injection grid). 124
Figure 85. Summary of PM results collected at the ESP outlet with and without PAC (using redesigned injection grid). 126
Figure 86. Trend of CPM data from B-West ESP (test—redesigned injection grid) and B-East ESP (control). 126
Figure 87. Size distribution of ash collected in first two fields. 129

INTRODUCTION

The power industry in the U.S. is faced with meeting new regulations to reduce the emissions of mercury compounds from coal-fired plants. Power plants that burn Powder River Basin (PRB) coal and have only cold-side electrostatic precipitators (ESPs) for air pollution control represent a challenging configuration for cost-effectively controlling mercury emissions. Full-scale field tests have confirmed that the average native mercury removal at these PRB units is low, typically < 25%. In addition, the effectiveness of injecting standard, non-chemically treated, activated carbon is greatly diminished by the low halogen concentrations in the flue gas.

ADA-ES, Inc., with support from the Department of Energy's National Energy Technology Laboratory (DOE/NETL) and industry partners, conducted a sorbent injection test program at Entergy's 880-MW Independence Steam Electric Station (ISES) Unit 2. During the program, the test team investigated the mercury capture and operational impacts of using the Electric Power Research Institute's (EPRI) patented TOXECON II™ process, a low-cost mercury control option that does not compromise fly ash sales. This report presents TOXECON II™ test results from two different configurations at a unit equipped with a cold-side ESP. It includes 1) the results on mercury control performance of injecting treated and untreated sorbents and a sorbent/ash recycle mixture, 2) a discussion of how the sorbent lance injection grid design influences its mercury removal performance and operability, and 3) the impacts of the TOXECON II™ process on ESP operation and particulate emissions.

EXECUTIVE SUMMARY

In order to further the understanding of potential mercury control systems for power plants burning Powder River Basin (PRB) coals and using cold-side ESPs for air pollution control, DOE selected ADA-ES, Inc., to conduct a sorbent injection test program at Entergy's Independence Steam Electric Station (ISES) for mercury control using activated carbon injection (ACI) in a EPRI TOXECON II™ configuration. During four months of field testing, the project team investigated the mercury capture and operational impacts of using the EPRI TOXECON II™ process, where activated carbon is injected into the flue gas stream in mid-ESP, thereby allowing power plants that do have the ability to sell the fly ash by-product to continue to do so for over 90% of the fly ash.

The primary objective of testing at Independence was to determine the cost and effects of sorbent injection using EPRI's TOXECON II™ for mercury control in stack emissions from Unit 2. Unit 2 was chosen for this evaluation because it is equipped with a medium-sized, cold-side ESP (SCA = 542 ft^2/kacfm) for particulate control.

Native mercury was primarily in the elemental form and removal was low. Less than 20% mercury removal was typically observed during four rounds of Baseline testing. While firing PRB coal, the ESP B inlet mercury averaged 7.9 lb/TBtu during Baseline tests while the ESP B outlet averaged 6.6 lb/TBtu. While firing ColoWyo coal, ESP B inlet mercury averaged 1.2 lb/TBtu. Independence typically fires PRB coal.

Ensuring proper sorbent distribution is critical for effective mercury control. Good distribution is more challenging with TOXECON II™ than injection upstream of the ESP for three primary reasons:

1) The flue gas velocity at full load within the typical medium-sized ESP is usually 3 to 4 ft/sec compared to 40 to 50 ft/sec in the duct upstream of the ESP. The air flow velocity is reduced by increasing the cross sectional area in the direction of flow within the ESP. The increased cross sectional area requires a much larger sorbent injection grid and poses a greater challenge for proper sorbent distribution within the ESP in comparison to the inlet ducting.

2) The penetration of the sorbent from the lance into the gas is affected by the velocity in the ESP, which can vary from nominally 1 to 4 ft/sec. Consequently, varying boiler load can significantly impact the pattern of sorbent distribution. In contrast, the velocity upstream of an ESP is typically 30 to 60 ft/sec and the sorbent penetration across the gas stream is minimal at all boiler loads. Using typical lance conveying air velocities of 10 ft/sec, the change in flue gas velocity in the duct from low to high load will result in a change in sorbent penetration of the flue gas stream by less than 30%. The same load change in the ESP, with it lower flue gas velocities, results in the doubling (or greater) of the plume size of the sorbent distribution pattern.

3) The distance between the injection lances and the downstream mechanical collection field is limited (nominally 3 feet at Independence Unit 2).

Significant effort was expended during the TOXECON II™ program at Independence to optimize sorbent distribution, including redesign of the sorbent injection grid and delivery system. Lance improvements resulted from extensive modeling efforts by ADA-ES (physical), NELS (physical), and Reaction Engineering International (CFD). Three lance designs were evaluated, including the original single multi-nozzle lance. The initial design was used to evaluate four powdered activated carbon (PAC) sorbents during Parametric testing: NORIT DARCO® Hg, DARCO® Hg-LH, DARCO® E-10, and DARCO® E-11. Results from these initial tests indicated that mercury removal was limited to less than 80% at injection concentrations up to 10 lb/MMacf. The four materials showed differences in their mercury removal performance, but not as great as was expected based on previous testing at PRB sites using treated and untreated PAC sorbents. In February and March 2007, tests with lances redesigned to improve the sorbent distribution yielded 89% mercury removal using DARCO® Hg-LH at 5 lb/MMacf.

Injecting PAC in the TOXECON II™ configuration resulted in particulate spikes during outlet field raps observed in the continuous particulate monitor and in the stack opacity during some testing periods. Increasing the ESP power and increasing the final field rapping cycle timing were effective at minimizing opacity spikes due to PAC injection. Although there was no indication of increased particulate emissions based upon outlet particulate EPA Method 5 measurements collected downstream of the ESP with and without PAC injection, additional testing is required to determine with any certainty whether TOXECON II™ implementation would result in a sufficient increase in particulate emissions to trigger a permit review.

As a budgetary estimate, a permanent sorbent injection system would cost \$4.3M ± 25%, on an installed basis in 2007 dollars. Assuming the use of DARCO® Hg-LH at a rate of 5 lb/MMacf, which would provide nominally 80% removal, the annual operating costs would be approximately \$8.69M ± 15% in 2007 dollars, including the cost of ash disposal and the revenue.

The goals for the program established by DOE/NETL were to reduce the uncontrolled mercury emissions by 50 to 70%, at a cost 25 to 50% lower than the target established by DOE of \$60,000/lb mercury removed. This goal was exceeded at Independence. Results from testing indicated that 80% mercury removal could be achieved using DARCO® Hg-LH at a sorbent cost 75% lower than the benchmark. The estimated costs for control at Independence are 1.49 mills/kWh, or \$14,500 per pound of mercury captured, while preserving the salability of the fly ash. Additional improvements to the injection system design to increase mercury removal by improving the sorbent distribution are anticipated with ongoing development of the technology.

DESCRIPTION OF OVERALL PROGRAM

The test program at Entergy's Independence Steam Electric Station (ISES) is part of a program funded by the Department of Energy's National Energy Technology Laboratory (DOE/NETL) and industry partners to obtain the necessary information to assess the feasibility and costs of controlling mercury from coal-fired utility plants using either high-temperature sorbents or EPRI's TOXECON II™ process. High-temperature sorbents were included in the test program at MidAmerican's Louisa Station. Sorbent injection into an electrostatic precipitator (ESP), TOXECON II™, is the focus of testing at Entergy's Independence Station. Both of the host sites fire Powder River Basin (PRB) coal and currently achieve less than 20% native mercury removal. At the onset of the program, American Electric Power's (AEP) Gavin Plant and MidAmerican Energy Company's Council Bluffs Station were also considered as potential host sites. After further consideration of the testing conditions at the AEP Gavin site, the test team dropped this site from the testing efforts. A portion of the funding allocated to testing at Gavin was transferred to a follow-on evaluation project at Independence in 4Q06. The Council Bluffs project was cancelled in 1Q07 due to lack of DOE project funding for FY 2008.

Key descriptive information for the final two host-site plants is included in Table 1. Table 2 shows the field test schedule for the final program. The technical approach followed during this program allowed the team to 1) evaluate various mercury control technologies at plants with different configurations, and 2) perform Long-Term testing at the optimum conditions for at least one month. These technical objectives were accomplished by following the series of tasks listed below. These tasks were repeated at both test sites.

Task 1: Site Coordination, Kickoff Meeting, Test Plan and QA/QC Plan

Task 2: Design and Install Site-Specific Equipment

Task 3: Sorbent Selection

Task 4–6: Field-Tests

Task 7: Data Analysis

Task 8: Sample Evaluation

Task 9: Site Report

Task 10: Technology Transfer

Task 11: Management and Reporting

A detailed description of each task is given in Appendix A1.

Table 1. Host site key descriptive information.

	Entergy Independence	MidAmerican Louisa
	TOXECON II™	**High-Temperature Sorbents**
Unit No.	1	1
Size (MW)	880	700
Test Portion (MW)	110/55	700
Coal	PRB	PRB
Heating Value (as rec'd.)	8,870	8,500
Sulfur (% by weight)	0.32	0.32
Chlorine (ppm)	50	50–100
Mercury (µg/g)	0.04	0.08
Particulate Control	Cold-Side ESP	Hot-Side ESP
SCA/fields (ft^2/kacfm)	542/4	459/5
Sulfur Control	Compliance Coal	Compliance Coal
Disposition of Ash	Sold	Sold
Typical Inlet Mercury (µg/dncm)	6–7	11.1–13.4
Typical Mercury Removal	10–20%	0–10%

Table 2. Field-testing schedule.

Site	2005		2006				2007	
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Louisa								
Independence								

There are several organizations participating in this program. The organizations providing co-funding for tests at Independence include:

DOE/NETL
EPRI
ADA-ES, Inc.
Entergy – Independence Steam Electric Station*
Alliant
ATCO Power
DTE Energy
Oglethorpe Power
Southern Company
Xcel Energy
NORIT Americas Inc.
Arch Coal
EPCOR

**Indicates host site.*

Key members of the test team include:

- Entergy Independence Station
  - Project Manager: Richard Roberts
  - Independence Project Engineers: Todd Bradberry, Steve Coker
  - Environmental Specialist: Kellee Fletcher
  - Fossil Environmental Support: Joe Hantz
- ADA-ES, Inc.
  - Project Manager: David Muggli/Sharon Sjostrom
  - Project Engineer responsible for all Site Activities: Tom Campbell
- DOE/NETL
  - Project Manager: Andrew O'Palko
- EPRI
  - Project Manager: Ramsay Chang
- Reaction Engineering International
  - Connie Senior

INDEPENDENCE PROJECT OBJECTIVES AND TECHNICAL APPROACH

The main objective of testing at Entergy's Independence Steam Electric Station was to determine the cost and effects of sorbent injection using EPRI's TOXECON II™ for mercury control in stack emissions from Unit 2. Unit 2 typically fires 100% western subbituminous PRB coal from the North Antelope mine. The unit is equipped with an electrostatic precipitator (ESP) for particulate control and uses compliance coal for SO_x control. The technical approach for this project consisted of two primary field activities: the design and fabrication of the sorbent injection system and field-testing. The general approach for the field-testing was to follow a series of subtasks as listed below.

1. Sorbent selection and screening
2. Sample and data collection coordination
3. Baseline tests
4. Parametric tests
5. Long-Term tests
6. Ash Recycling tests

Parametric and Long-Term test conditions were chosen to meet an overall objective of evaluating the TOXECON II™ system for enhanced mercury removal at cold-side ESP units firing PRB coal. TOXECON II™ is a retrofit mercury control technology that requires minimal capital investment because it requires only minor retrofits to the ESP for the sorbent injection system instead of installing a separate, secondary particulate control device. A sketch of the concept is shown in Figure 1. The primary benefit of the TOXECON II™ process is that typically 90+% of the fly ash is collected in the ESP prior to sorbent injection, dependent upon the injection grid location. With TOXECON II™, sorbent is injected between the mechanical collection fields of an ESP, generally after the first two fields, allowing the untreated ash to be segregated from the treated sorbent/ash mixture through the design of the ash handling system. Thus, the advantage for plants such as Independence that typically sell fly ash for use in concrete is that TOXECON II™ maintains the salability of most of the ash.

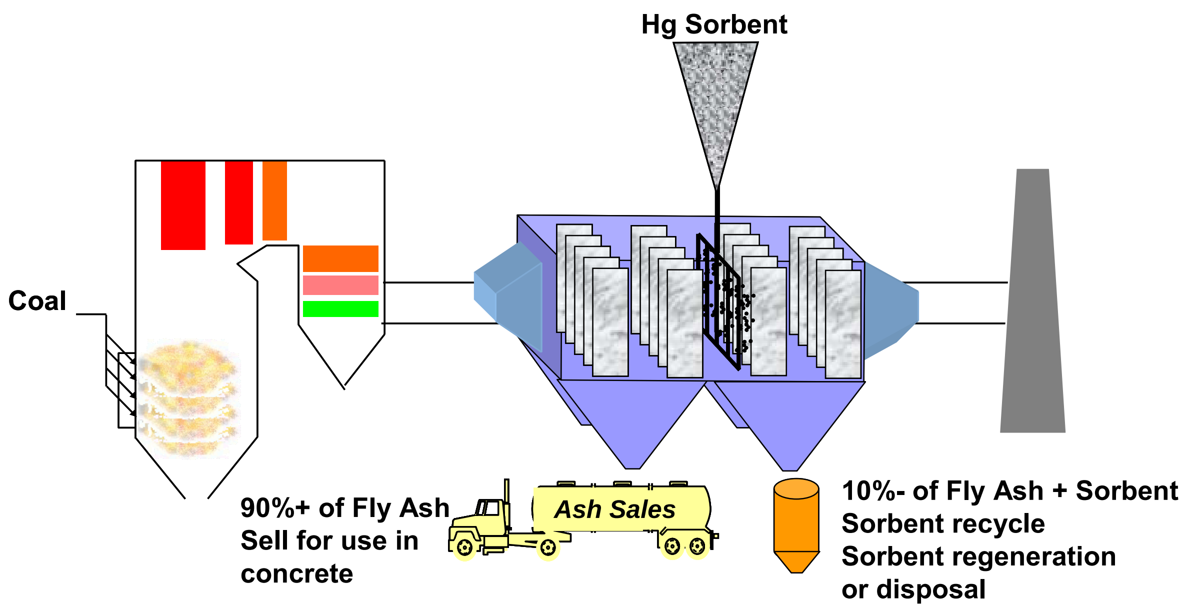


Figure 1. TOXECON II™ general arrangement.

The evaluation at Independence Unit 2 focused on activated carbon injection (ACI) using treated and untreated sorbents and the particulate pass through of the TOXECON II™ system. Reinjection of collected sorbent/ash mixture was also evaluated for mercury control.

Preliminary analyses indicated that the TOXECON II™ process required higher than expected sorbent concentrations to achieve significant mercury removal at Independence. Consequently, the test team established an additional objective: evaluate the possibility that the sorbent injection grid failed to distribute sorbent uniformly or its injection nozzles became plugged.

To determine further whether the sorbent usage requirements were a result of poor sorbent distribution, EPRI funded three independent modeling efforts:

1. Computational Fluid Dynamics (CFD) modeling by Reaction Engineering International
2. Physical modeling of the ESP and injection grid by NELS Consulting Services
3. Physical modeling of the lance design by ADA-ES

An outcome of the modeling efforts included redesigning the sorbent injection grid and delivery system and its subsequent evaluation. The results of this follow-on test program are also presented here. Most of the early evaluations were conducted on 1/8 of the 880-MW Unit 2 flue gas stream (Appendices A1–3 and A5); later evaluations were generally on 1/16 or 1/32 of the unit (Appendix A4).

Importance of Testing at Independence

The project team selected Independence Unit 2 as the TOXECON II™ test site because it was representative of a significant number of coal-fired plants constructed from 1970 to 1990. Independence is configured with a cold-side, large-sized ESP (SCA = 542 ft^2/kacfm) and fires pulverized PRB coal. Moreover, the ESP is controlled by a Neundorfer control system, thus enabling several parameters to be monitored. Another key feature of Unit 2 is that it has the ability to modify its fly ash collection procedure. A percentage of the fly ash becomes mixed with sorbent downstream of the injection grid during the TOXECON II™ process. Because the sorbent/fly ash mixture from each row of collection hoppers could be separately collected, Entergy maintained the option to sell most of their fly ash and the effectiveness of recycling the sorbent/fly ash mixture could be tested.

The physical layout of the ESP and combination of control features allowed the TOXECON II™ process to be evaluated in two configurations: the first with PAC injection upstream of two collection fields and an effective SCA = 270 ft^2/kacfm and the second with injection upstream of a single collection field and an effective SCA = 135 ft^2/kacfm. Independence is operated as a swing load unit, therefore responding to rapid large swings in load conditions, allowing further evaluation of the performance of the mercury removal system.

Limited data are available for mercury removal using the TOXECON II™ injection configuration. In an earlier short-term test at the Great River Energy Coal Creek station (a lignite-coal-burning plant), TOXECON II™ showed a 50% reduction in mercury emissions at sorbent injection rates of 1.25 lb/MMacf. With these results, the overall mercury removal costs are only 10 to 15% of what was estimated in DOE and Environmental Protection Agency (EPA) cost projections. The project at Independence provided the opportunity to evaluate sorbent injection using the TOXECON II™ injection system through both short-term Parametric testing and over a 30-day Long-Term testing period. The Long-Term testing period was aimed at identifying balance-of-plant impacts that may not be apparent during the shorter test.

Independence Site Description

General Description of Unit 2

The Independence Steam Electric Station is located in Independence County, Arkansas, near the town of Newark and consists of two load-following 880-MW (gross) pulverized coal, electric generating units that burn PRB coal. The boiler is a balanced-draft Combustion Engineering tangentially fired divided-furnace. Compliance coal to control SO_x emissions and over-fire air is used to reduce NO_x emissions reductions. The combustion controls use a proprietary neural net scheme to monitor performance, limiting operator intervention and allowing long-term steady-state conditions. Gas exiting the boiler enters two Ljungström regenerative air preheaters (APH), each with its own outlet duct. The test unit (Unit 2) is equipped with a cold-side ESP for particulate removal. The ESP consists of four boxes arranged in a piggyback configuration, two on top and two on the bottom, operating in parallel. Further description of the ESP is provided below. Each APH outlet duct feeds one of the stacked pairs of ESP boxes. Key operating parameters for Unit 2 are included in Table 3.

Table 3. Independence Unit 2 key operating parameters.

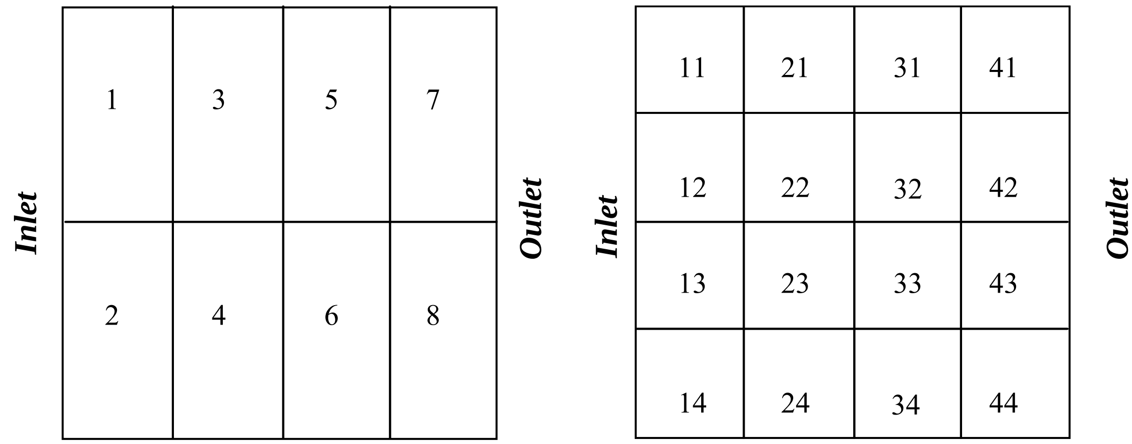
Unit	2
Size (MW)	880
Test Portion (MWe)	26 to 106
Flue Gas Flow (kacfm)	3,200
Coal	PRB
Heating Value (Btu/lb, as received)	8,600–8900
Sulfur (% by weight, dry)	< 0.4
Chlorine (%)	< 0.01
Mercury (µg/g)	0.03–0.08
Particulate Control	Cold-Side ESP (SCA = 542 ft^2/kacfm)
Sulfur Control	Compliance Coal
Air Pre-Heater	Regenerative
Ash Reuse	Sold

Independence is a load following plant; each unit provides load for a different electrical grid and can only be cross-connected with difficulty. A unit responds to the load dispatch requests for load changes as needed. The neural net control system used allows Unit 2 to change load at approximately 25 MW per minute, and can go from under 300 MW to over 800 MW in less than an hour.

ESP Test Box Description

Each of the four Unit 2 ESP boxes has eight transformer-rectifier (TR) sets and 16 ash collection hoppers, configured as shown in Figure 2. The boxes are a CE Walther rigid-frame construction and have collection plates running the width of a box with 12-inch plate-to-plate spacing. The structural steel and the plug flow between the collection plates minimize the crossover of the flue gas between the two halves of a box.

Each box was initially designed as a hot-side ESP prior to operation as a cold-side ESP. This design feature provides for lower velocities within the ESP box than typical for most cold-side ESPs. Duct flue gas flow velocities prior to the ESP inlet are maintained at normal rates (approximately 50 fps) through the addition of bluff bodies in the ductwork, restricting flow areas and increasing velocities. Approximately one-fourth of the total flue gas stream passes through each box. For a given stacked pair of boxes, both ends of one-half of one box are connected to the matching halves of its partner via vertical ducts; i.e., each pair has two inlet and two outlet ducts.



ESP Electrical Fields **ESP Ash Hoppers**

Figure 2. ESP electrical field and ash hopper configuration and numbering scheme.

The combination of the above features made it convenient to use one ESP box both for testing and as a control even though the two halves of the box are not physically divided. The lower ESP box (designated “B”) of the northern pair of boxes was selected for testing purposes. Testing on B-box minimized the sorbent transport distance from the most convenient location for the injection system skid and PAC storage silo. The west side of B-box (containing electrical fields 1, 3, 5, and 7) was designated the test side and the east side (containing electrical fields 2, 4, 6, and 8) as the control side. A line schematic of the one-half of the gas flow is shown in Figure 3. A photo showing the north access to the ESP B/D pair of outlet ducts is given in Figure 4. Details of the sorbent injection grid and monitoring locations are described later. A photo of NELS’ 1/12 scale physical model of the one-half of one ESP box is presented in Figure 5 for additional reference.

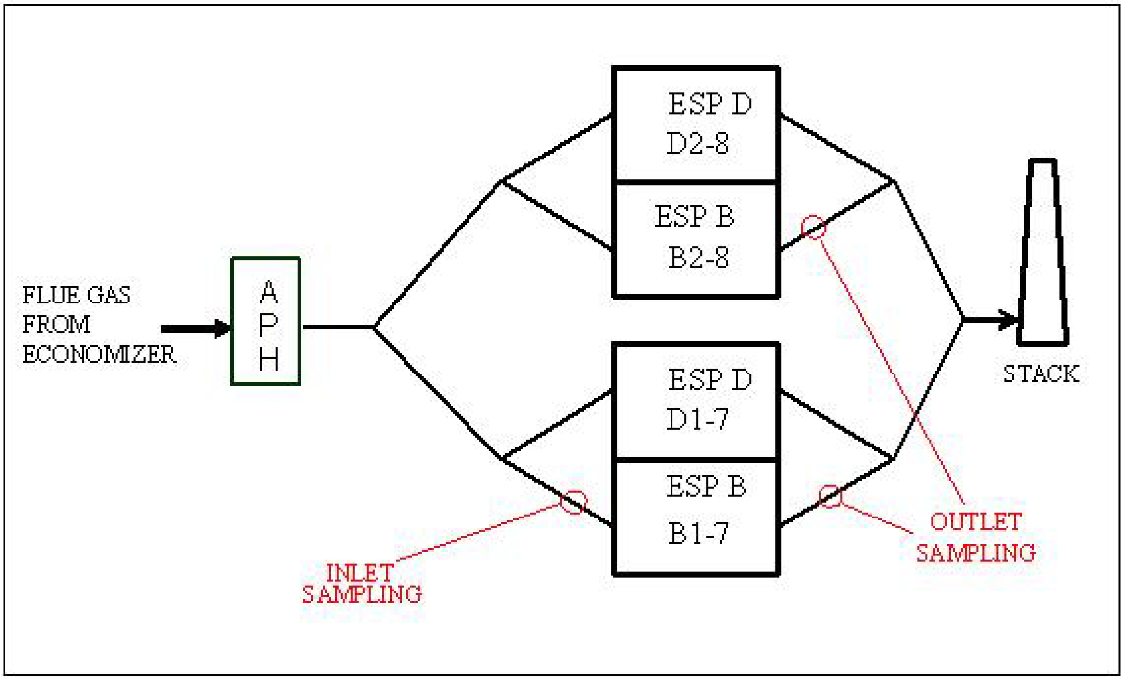


Figure 3. Line schematic of one-half of the Unit 2 flue gas flow.

Figure 4. Photo of north ESP B/D outlet duct–Unit 2.

Figure 5. Photo of NELS 1/12 scale model. One-half of one Unit 2 ESP box. (Third field plates removed in photo.)

ESP Control System

The plant has programmed the Neundorfer ESP control system to monitor the amount of ash each hopper collects. This feature allows differences in hopper collection to be monitored, e.g., during injection and non-injection periods and when injection locations are changed. Moreover, the ESP control system can easily change the plate and discharge electrode rapping cycle, both duration and timing, thereby providing data to analyze the impact of rapping changes to the ESP operating parameters.

Another function of the ESP control system is the Precipitator Optimization System (POS). This function allows the ESP control system to monitor several parameters such as plant opacity, back corona, etc., and to vary the entire ESP power output to minimize power usage while maintaining opacity within target limits. The POS also allows separate TR sets to be removed from its control and operated manually to quantify the impact of varying power levels on the particulate emissions.

Ash Handling System

The fly ash handling system is a dilute phase pressure system with pressure feeders at each ESP hopper outlet, and has two storage silos—typically one allocated for each generating unit. During test periods involving carbon injection and for separate Entergy-sponsored test runs of a Colorado-mined higher Btu coal, the system segregated the ash/carbon mixture from the hoppers under the corresponding test fields. Usually once per day, the plant would manually initiate the ash removal from the carbon-loaded hoppers for transport to the dedicated segregated storage silo. This practice allowed separate storage of the carbon/ash mixture for either disposal or for reclaim for use during the ash recycle testing. Although Independence Unit 2 normally burns 100% PRB coal, for several short periods during the testing, the plant burned a western bituminous coal from the ColoWyo mine. When the ColoWyo coal was burned, the plant transported all of the ash to the dedicated test silo.

Sorbent Injection and Monitoring Locations

Sorbent Injection Locations

Two independent sections each of sorbent injection grids were placed at two locations within the ESP B-box. The first dual injection location was between electrical fields B-3 and B-5 and the second dual injection location was between electrical fields B-5 and B-7. A representative sketch of the test configuration is given in Figure 6. As will be described in greater detail later, some injection tests used only a portion of the dual injection grid at a single injection location.

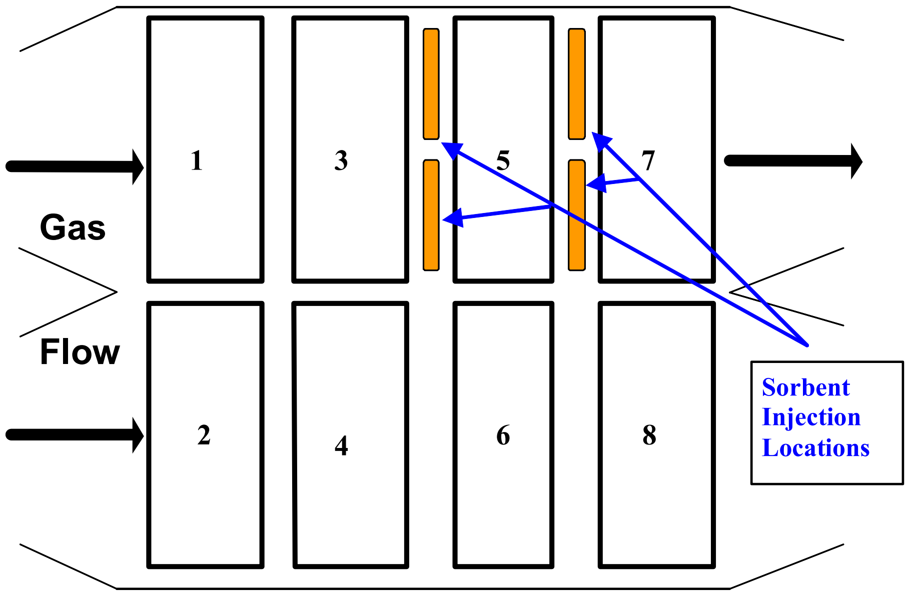


Figure 6. Plan view sketch of electrical fields for ESP B-box showing sorbent injection grid locations.

Flue Gas Sampling Locations

During testing on Unit 2, flue gas was sampled from the vertical inlet and outlet ducts of the ESP B-box. The inlet ducts to the box have an internal divider island resulting in a dead space in the center of each duct. This divider was installed during the hot to cold-side ESP conversion. It serves to maintain flue gas velocities and thus minimize fly ash from dropping out in the ducts. Both the inlet and outlet ducts contain a horizontal strip of access ports. The B-box test side inlet duct port locations and numbering as viewed from the top of the box are shown in Figure 7. The outlet port configuration differs slightly from the inlet. On the inlet duct, port 4 is approximately 10" closer to port 3 than on the outlet duct. Port 5 on the inlet is blocked by a diagonal structural brace. The outlet test port access was somewhat restricted due to interference from the TR sets.

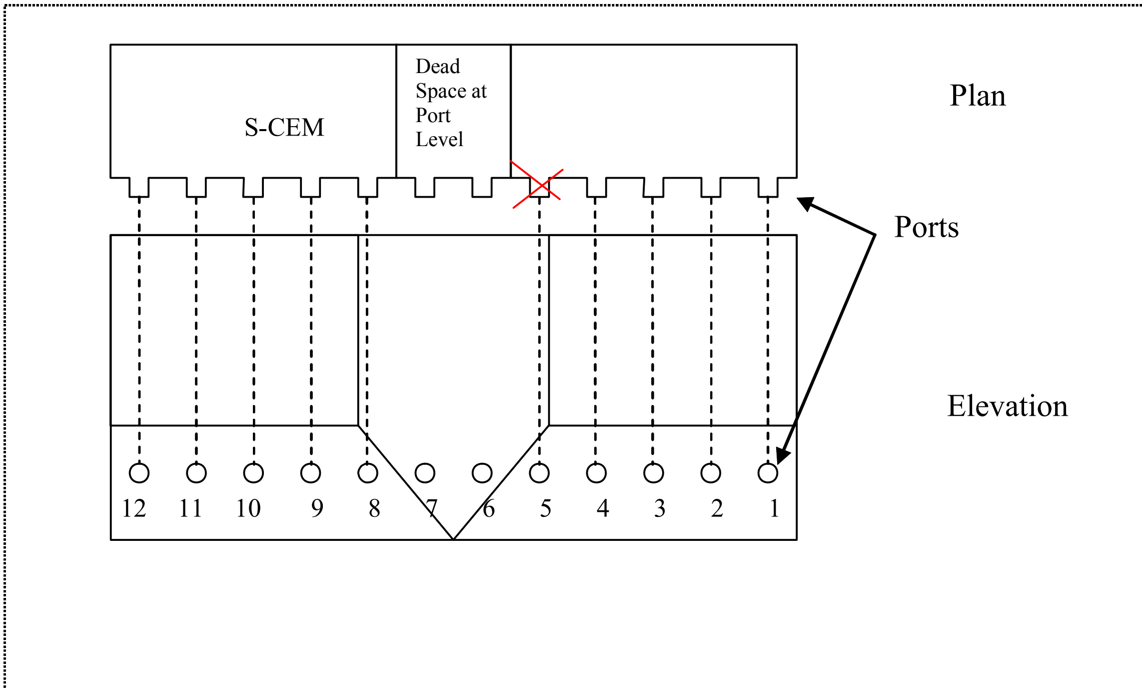


Figure 7. ESP B test side inlet duct access port configuration; plan view (top) and elevation view (bottom). Port 5 was blocked.

Two mercury Semi-Continuous Emissions Monitors (S-CEMs) were used during the test period to monitor both upstream and downstream of the ESP B-box. All upstream S-CEM mercury measurements were taken from the inlet duct on the test side of the B-box. Downstream mercury measurements were taken from the vertical outlet ducts on both the control side (Total Mercury Concentrations only) and test side (both Total and Elemental Mercury concentrations) of the B-box. During initial testing, port 9 on the test inlet duct and test outlet duct were used as the location for monitoring vapor-phase mercury on the ESP B-box. After the August 2005 tests, the test outlet monitoring location was primarily from port 8 when injecting across the entire injection grid or port 2 when injecting across half (west side) of the test side ESP. In addition to the S-CEM mercury monitoring, Sorbent Trap Method (STM) mercury measurements were taken from the B-box test side inlet and outlet ports throughout the test period. Continuous particulate monitors (CPMs), both opacity sampling (BHA CPM 5000) and direct particulate measurement (Thermo Scientific TEOM Series 7000) CPMs, were used to monitor particulate emissions in the outlet ducts of both the control side and test side of the B-box. The downstream monitoring locations were in-line with the sorbent injection grid lances to assure representative outlet measurements. The sketch in Figure 8 depicts the locations of the S-CEMs and the CPM (BHA CPM 5000) for the test side of the B-ESP. The TEOM Series 7000 was installed in one of the test side outlet ports next to the test side S-CEM. A second BHA CPM 5000 was installed on the control side of the B-ESP to monitor variations in opacity across the outlet ducts of the B-ESP during injection periods.

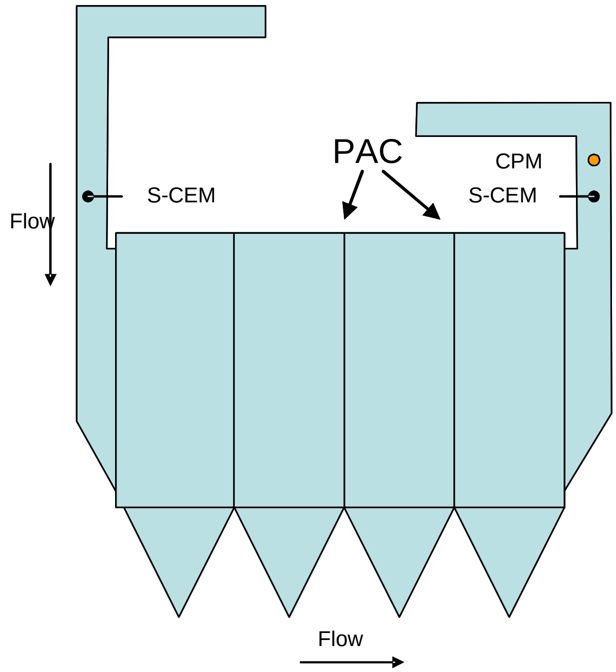


Figure 8. Elevation sketch of ESP B-box at Independence Unit 2. Indicates injection and monitoring locations for the west half of the box.

Equipment Descriptions

Sorbent Delivery Systems

Two separate methods were used to deliver sorbent for test injection: a NORIT Americas Porta-PAC™ system used for most Parametric testing and a silo delivery system used for Long-Term and ash recycling testing. Both methods use a similar feed system whereby the sorbent is metered by variable speed screw feeders into eductors. Regenerative blowers provide the conveying air to the eductor and the air-sorbent mixture then flows to the injection points. Figure 9 is a photo showing the Porta-PAC™, carbon injection silo, and feeder trains at the Independence test site.

Figure 9. Porta-PAC™ and carbon injection storage silo and feeder trains at the Independence test site.

The auger feed rate is calibrated by measuring the rate that sorbent flows into a collection bag for a given number of auger revolutions. The flow rate (lb/hr) is determined by dividing the weight of the collection bag by the collection time period. Adjustments to the controller set point compensated for feed screw wear as well as different sorbent densities. This calibration procedure applies to both the Porta-PAC™ and silo delivery systems.

The sorbent feeder was configured to adjust the feed rate based upon on a feed-forward signal from the plant representing the amount of coal fed into the boiler. An algorithm was developed to correlate coal feed rate to duct flow (using a load signal from the plant to the silo PLC) so that the sorbent injection concentration could be maintained with variations in load.

Prior to the TOXECON II™ follow-on testing period, the regenerative blower was replaced. The replacement blower is configured with a variable speed blower and has a maximum rated flow of 700 cfm. This flow rate was larger than required, but allowed for flexibility during the demonstration program. A photo of the blower is shown in Figure 10.

Figure 10. Upgraded blower system used in 2007.

Porta-PAC™ Delivery System

For most Parametric tests, sorbent was delivered by a NORIT Porta-PAC™ system, which consists of a portable blower/feeder train with a hoist for holding 900-lb super-sacks of sorbent. The sorbent filled super-sacks are delivered to the site on a flat bed trailer and are individually loaded onto the Porta-PAC™ unit, enabling an easy transition from one sorbent to another without contamination or waste. During testing at Independence Unit 2, flexible hose was used to transport the sorbent from the feeder to the distribution inlet manifolds located at the top of the ESP test B-box.

An individual super-sack contains sufficient sorbent for approximately 8 hours of testing at the typical Parametric test injection conditions at Independence (full load, steady state conditions). The Porta-PAC™ system can adjust the feed rate based on a plant load signal input into the feeder controller. However, the Porta-PAC™ feed rate was operated manually for Parametric testing because the plant was operating steadily at full load conditions. During Parametric testing, feed rate calibrations occurred once per day, immediately prior to the start of a test. If the feed rate appeared to have varied during the test, a second calibration was performed at the end of the test.

Storage Silo Delivery System

The ACI delivery system for the Long-Term tests consisted of a bulk-storage silo, with approximately 20-ton storage capacity, and twin blower/feeder trains. Powdered activated carbon (PAC) was delivered by bulk pneumatic truck and pneumatically conveyed into the silo which is equipped with a bin vent bag filter. Sorbent was fed from the silo into the feeder trains where it was mixed with transport air and conveyed to the distribution inlet manifolds at the top of the ESP test B-box. The transport air quantity was constant, but a variable speed screw feeder metered the sorbent into the transport air through an eductor. A programmable logic controller (PLC) system controlled the delivery system operation, allowing testing at various sorbent injection rates or the system to respond to load changes by the unit.

During Long-Term testing, feed rate calibrations occurred once per week and the actual feed rate continuously checked against the change in silo weight determined from load cells on the silo support legs. For Long-Term testing, actual feed rates were 1.1 times the indicated feed rate on the controller, e.g., an indicated feed rate of 4 lb/MMacf corresponded to an actual feed rate of 4.4 lb/MMacf. All test results are based on the actual feed rate.

<u>TOXECON II™ Injection System</u>

ADA-ES had previously performed a brief test of the TOXECON II™ concept at the Great River Energy Coal Creek station. Owing to the high levels of mercury removal observed at Coal Creek, its grid design was used as the basis for the initial grid design at Independence Unit 2 without an attempt to model the injection distribution. However, the Coal Creek design required higher than expected sorbent concentrations at Independence to achieve satisfactory performance. After the completion of the initial 30-day Long-Term and follow-on continuous injection period during October through December 2005, the injection grid was modeled and then redesigned in an attempt to improve its performance.

Initial Injection Lance Grid Design

The ESP B existing internal structural steel and the arrangement of the discharge electrode support frames dictated the design and placement of the sorbent injection grids. In order to maintain sufficient clearance between the injection grids and the energized discharge electrode frames, each injection location consisted of two separate grid assemblies. That is, two grids were placed side-by-side perpendicular to the air flow direction through the ESP between fields B-3 and B-5 and also between fields B-5 and B-7, for a total of four separate grids (see Figure 6 for a sketch of the grid locations).

Complete injection grids were installed within the test side of the B-box, each with a single inlet connection at the top of the box to minimize penetrations through the ESP insulator penthouse. An injection grid assembly consisted of a horizontal header with eight equally spaced vertical ports. Individual injection distribution pipes (lances) were suspended vertically from each port. Each lance had eleven nozzles of varying sizes to distribute the air-sorbent mixture between the electrical fields. The two outer lances, one on each side, had a lesser number of ports to minimize PAC distribution into the side wall and vertical structural steel supports. The injection nozzles were spaced equally along a lance except for minor variations necessary to avoid PAC discharging directly onto diagonal structural steel members. A schematic showing two side-by-side injection grid assemblies is given in Figure 11.

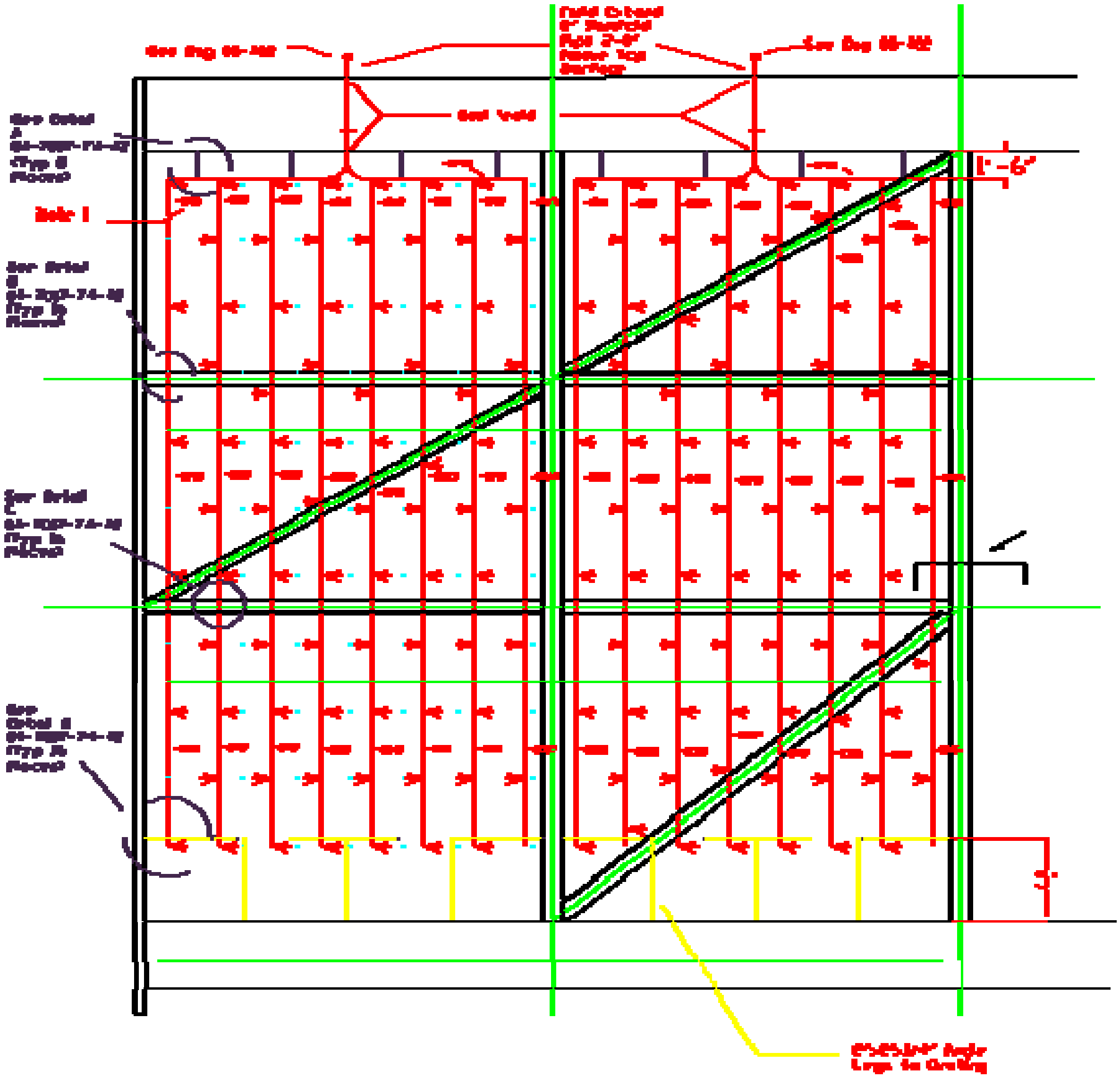


Figure 11. Schematic of injection grid.

The injection grids were located in the open space between the collection plates. To allow maximum residence time, the grids were placed upstream of the structural steel supports that separate each collection field. Grid placement was as close as possible to the structural steel supports to maximize distance between the grounded injection grid and the upstream high voltage discharge electrode frame. Figure 12 shows a photo of an injection grid within the Unit 2 B-box. This configuration provided approximately 1-second residence time before the PAC (injected at high unit load) entered the collection plates of the downstream field.

Figure 12. Injection grid between ESP fields.

Redesigned Injection Lance Grid

Redesigned injection lances were installed at Independence prior to the 2007 round of testing. The redesigned lances require additional carrier air delivered to the nozzles to achieve adequate carbon distribution in the TOXECON II™ configuration. This air delivery requirement could be met with the new regenerative blower that was installed prior to this round of testing.

The new injection grid consists of three lances installed into each of 8 injection ports. Each of the three lances treats a section of the ESP B-box approximately 15 feet deep through a series of eight injection nozzles placed on 3’ 8” centers (two nozzles are located at each elevation). Coverage across the ESP is achieved by overlapping the distribution patterns of adjacent lances. Figure 13 shows a sketch of the lance configuration. The initial design had a single ESP box penetration for each set of eight lances. This minimized the number of penetrations required through the penthouse, but prevented lance removal without bringing the unit off-line. The new design incorporated a means to remove lances on-line, allowing a much more cost effective approach to replacement and maintenance for the system.

A second redesign of the injection system was then made to minimize potential pluggage during operation. A multi-ported nozzle was placed at the bottom of each lance to maximize PAC spray dispersion from each nozzle. The nozzles in each adjacent port were offset in vertical height to increase PAC coverage. The penetrations through the ESP penthouse remained the same as on the first redesign.

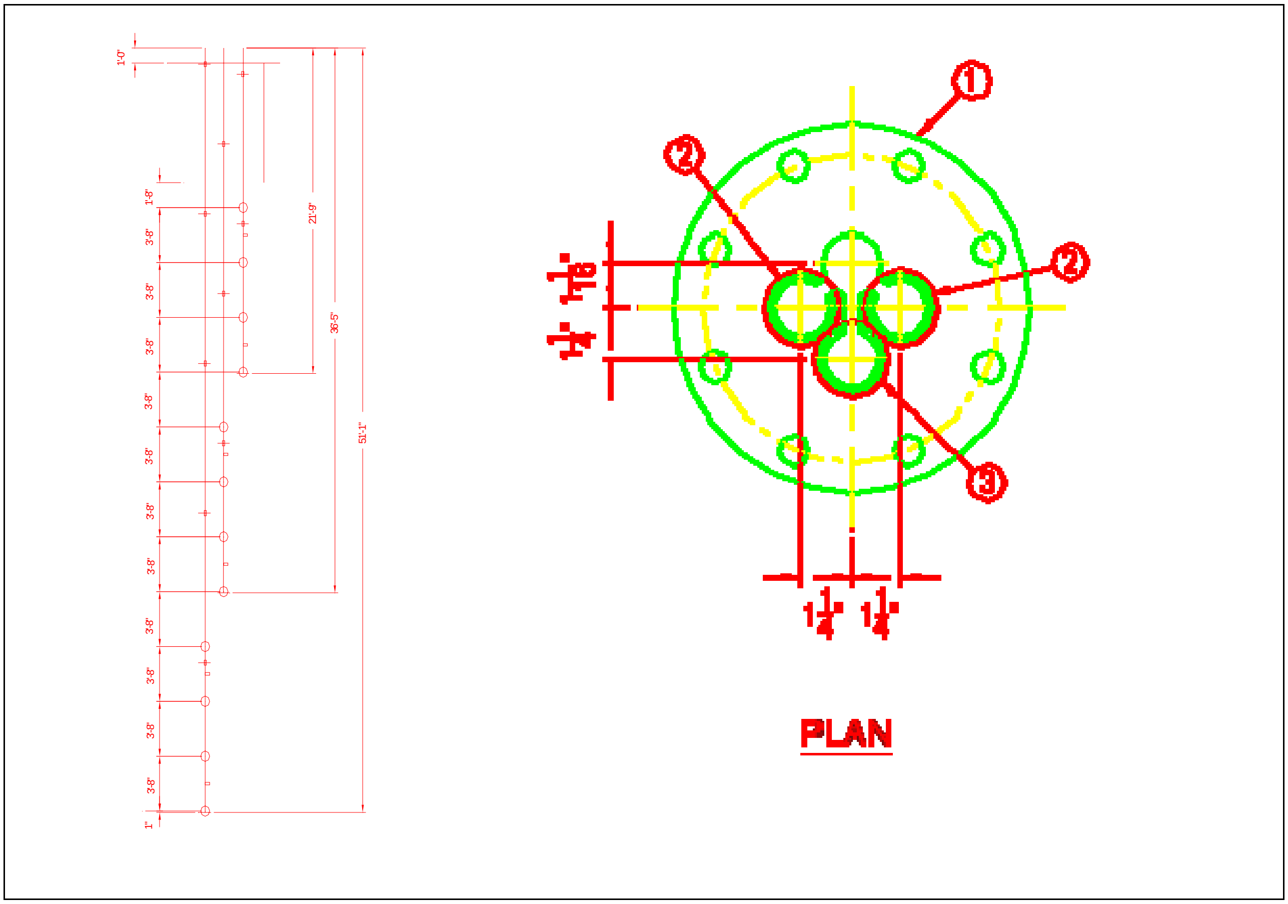


Figure 13. Redesigned multi-port lance.

Mercury Monitoring System

During the primary test program, two mercury S-CEMs were used to provide real-time feedback of the mercury levels in the flue gas entering and exiting the ESP B-box. During the extended test period, only one S-CEM was used. An S-CEM consists of a sample extraction and conditioning system connected to an analyzer system with a heated sample transport umbilical bundle. The extraction probe is an inertial separation design that separates the particulate matter from the sample with minimal sampling artifacts from fly ash or injected sorbent. Figure 14 shows a sketch of the system along with a picture of the mercury analyzer. An analyzer consists of a cold vapor atomic absorption spectrometer (CVAAS) coupled with a gold amalgamation system (Au-CVAAS) and is calibrated using vapor-phase elemental mercury.

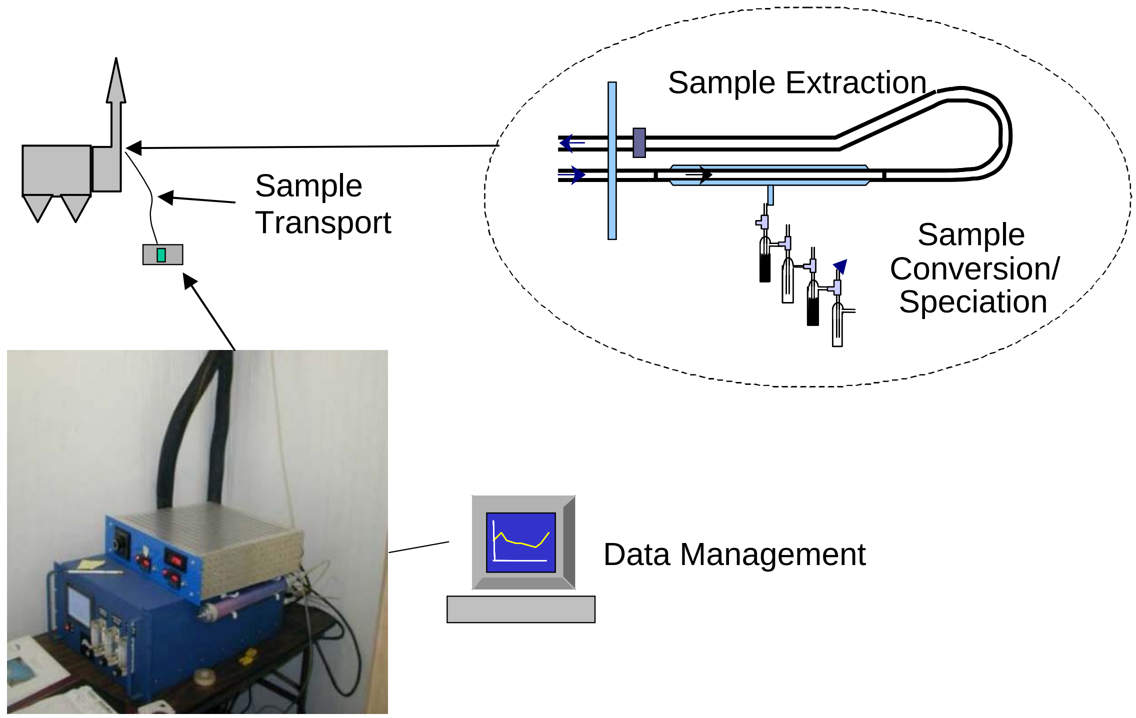


Figure 14. Sketch of mercury measurement system.

The analyzer measures both total vapor-phase mercury and elemental vapor-phase mercury. It determines total vapor-phase mercury concentrations by chemically reducing all of the oxidized mercury to the elemental form near the extraction location. The oxidized mercury is then removed, allowing the elemental mercury to pass through without alteration for measurement.

Sorbent Trap Equipment and Analysis

The method of using activated carbon traps for measuring mercury at coal-fired power plants has been given several acronyms over the past few years such as Quick SEM or QSEM (EPRI trademark), and used as the basis for EPA Draft Method 324 or M324, Appendix K of Title 40 CFR Part 75 under the title "Quality Assurance and Operating Procedures for Sorbent Trap Monitoring System," and most recently EPA Method 30B. For this report, it will be referred to as the Sorbent Trap Method (STM). The method involves inserting a glass tube filled with activated carbon into a gas stream and drawing a measured amount of gas across the carbon trap. The paired traps can then be sent to a lab and analyzed for mercury. The test program at Independence included use of equipment manufactured by Apex Instruments, Environmental Supply Company (ESC), and a gas metering box designed by ADA-ES. Further details of STM are contained in Appendix B.

Particulate Monitors

The test program used two different kinds of particulate monitors to characterize the ESP outlet flue gas particulate emissions during Baseline testing and sorbent injection: the Thermo Electron TEOM Series 7000 Source Particulate Monitor and the BHA CPM 5000 monitor. Emissions data gathered with these devices at the outlet ducts of ESP B-box were analyzed to better quantify the effects of injecting sorbent on ESP collection efficiency.

Thermo Electron TEOM Series 7000

The TEOM Series 7000 Source Particulate Monitor is a single point continuous particulate monitoring device that determines flue gas velocity, collects particles isokinetically on a filter for gravimetric analysis, and performs a direct measurement of their mass over time to give a continuous particulate loading indication. The particulate matter (PM) concentration in a flue gas stream can be made directly because the monitor's mass transducer, along with the collection filter, is placed inside of the duct or stack. The Series 7000 monitor performs its filter-based mass measurement using an industrially hardened tapered element oscillating microbalance. This system has received conditional test method approval for U.S. EPA Methods 17 and 5 (front half) and meets all of the requirements of the new American Society of Testing and Materials (ASTM) Standard Test Method D6831-02.

One TEOM Series 7000 monitor was installed in the ESP B-box test outlet duct. The device is designed only for short-term unattended operation. Consequently while in use during the testing at Independence, the sample probe had to be pulled from the outlet duct every few days to change the filter element. Prior to conducting tests, the test team performed a duct temperature/velocity traverse to provide a reasonable approximation of particulate loading for the entire duct and subsequently to position the sampling point of the monitor to sample at an average duct flow point.

BHA CPM 5000

The CPM 5000 monitor is an optical measurement device that measures particle flow across a beam of visible light. The device is sensitive to particle size, distribution, and characteristics. A transmitter and receiver are placed on opposite sides of the stack or duct. When dust particles pass between the transmitter and receiver, they momentarily block the light causing the receiver to see a modulating signal from the transmitter. The signal modulation is proportional to dust concentration. Because the device does not measure mass directly, it requires calibration using an EPA Method 5 or 17 duct traverse test.

BHA CPM 5000 particulate monitors were installed across the outlet ducts of both the test and control sides of the ESP B-box. The CPM 5000 instruments were calibrated against the TEOM Series 7000 and the Method 17 runs during Baseline testing.

In-Situ Fly Ash Sampling Device

The in-situ fly ash sampling device consists of a cyclone separator, venturi flow meter, and an eductor. The PM2.5 cyclone was designed to measure particulate emissions under Method 201A. The cyclone is designed to collect particulate 2.5 microns in diameter and greater. By operating the cyclone at higher than design flow rates, smaller diameter particles can be collected. A photo of the cyclone sampler is included in Figure 15.

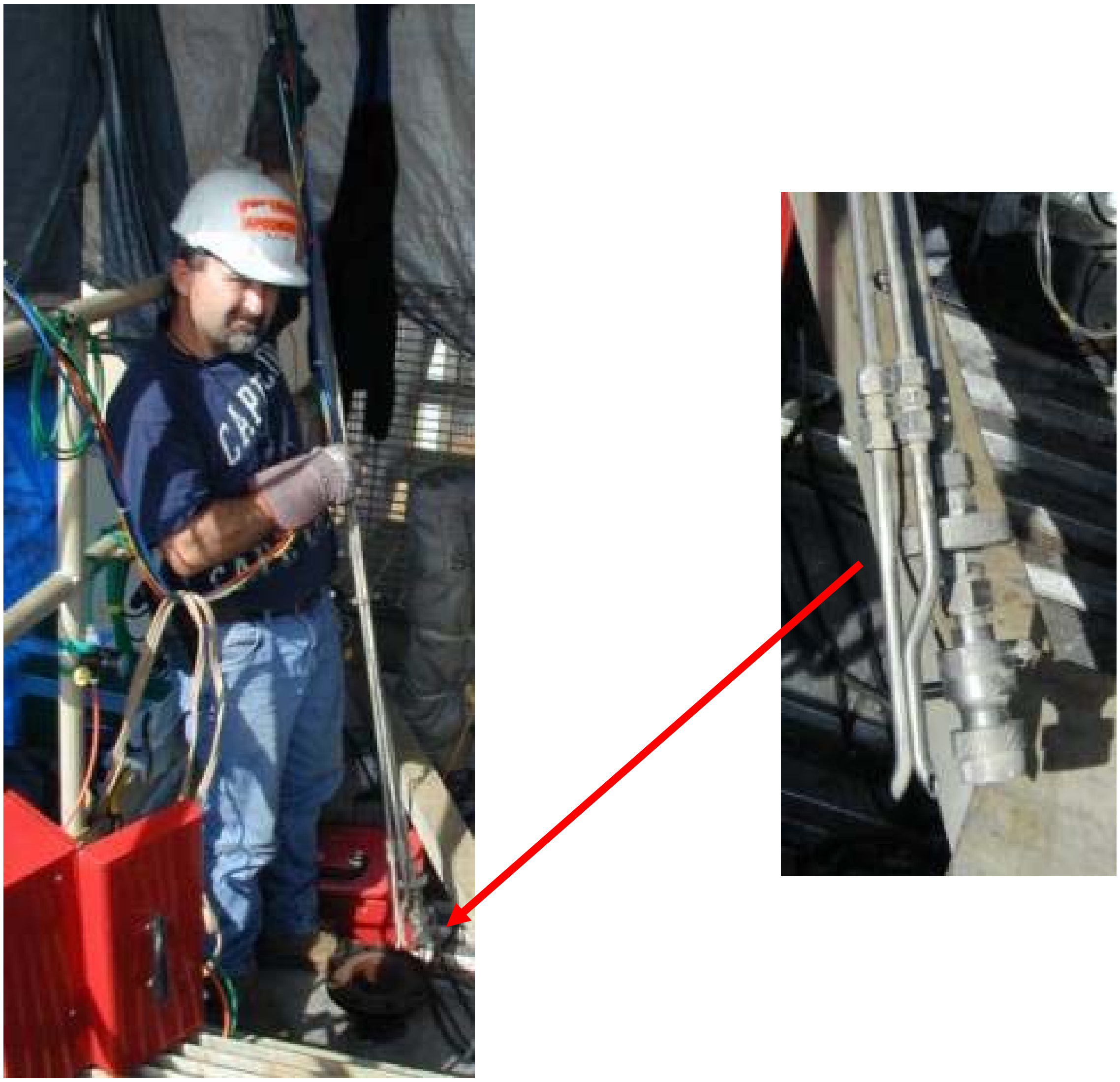


Figure 15. In-situ fly ash sampling device.

Description of Field Testing Subtasks

The Independence field tests were accomplished through a series of four subtasks: 1) sample and data coordination, 2) Baseline testing, 3) Parametric testing, and 4) Long-Term testing. The subtasks are independent from each other in that they each have specific goals and tests. However, they are also interdependent, as the results from each subtask influenced the test parameters of subsequent tasks. A separate field subtask, evaluating ash/carbon recycling was also undertaken.

The initial testing schedule was interrupted due to plant equipment outage. When the equipment became operational, a second round of Baseline and Parametric testing was conducted prior to commencing Long-Term tests. At the conclusion of the originally scheduled test sequence, the test program was extended through supplemental EPRI funding to include additional Baseline, Parametric, and Long-Term testing of a redesigned injection grid and delivery system. A summary of each subtask is presented in the following sections.

The complete test sequence is presented in Table 4. For more details on the test program, reference Appendix A for Test Plans 1–5 and Appendix C for Field Test Logs 1–3.

Table 4. Field-test sequence at Independence.

Test Description	Test Dates	Parameters/Comments
Preliminary	8/01/05–8/05/05, 8/08/05–8/12/05	Days 1–2: Equipment setup Days 3–5: Duct traversal to determine sample ports Day 5: S-CEMs and CPMs operational Day 7: Dual sample STM inlet and outlet Days 8–9: Single sample STM outlet
Baseline (Round 1)	8/15/05–8/21/05	Day 1: Baseline measurements Days 2–4: ASTM M6784-02, M26A, M5/17 Day 5: Baseline measurements
Parametric Testing (Round 1)	8/22/05–8/25/05	Day 1: DARCO® Hg: 3, 6 lb/MMacf; upstream of field B-5[a] Day 2: DARCO® Hg-LH: 1, 3, 6 lb/MMacf; upstream of field B-5 Day 3: DARCO® Hg E-10: 3, 6 lb/MMacf; upstream of field B-5 Day 4: DARCO® Hg E-11: 3, 6 lb/MMacf; upstream of field B-5 (Ongoing: monitor particulate emissions and ESP electrical conditions)
		No testing
Parametric Testing (Supplemental opacity)	9/08/05–9/09/05	Day 4: DARCO® Hg-LH: 3, 6 lb/MMacf; upstream of field B-5 Day 5: DARCO® Hg: 3, 6 lb/MMacf; upstream of field B-5
		No testing during plant repairs
Baseline (Round 2)	9/28/05–9/30/05	Days 1–3: Baseline measurements (Ongoing: monitor particulate emissions and ESP electrical conditions)
Parametric Testing (Round 2)	10/01/05–10/08/05	Day 1: DARCO® Hg E-10: 3, 6 lb/MMacf; upstream of field B-7[b] Day 2: DARCO® Hg E-11: 3, 6 lb/MMacf; upstream of field B-7 Day 3: DARCO® Hg: 1, 3 lb/MMacf; upstream of field B-7 Day 4: DARCO® Hg: 6, 8 lb/MMacf; upstream of field B-7 Day 5: DARCO® Hg-LH: 0.5, 1 lb/MMacf; upstream of field B-7 Day 6: DARCO® Hg-LH: 3, 6 lb/MMacf; upstream of field B-7 Day 7: DARCO® Hg-LH: 3 lb/MMacf; upstream of fields B-5 and B-7, separately Day 8: DARCO® Hg-LH: 3 lb/MMacf; upstream of field B-5 or B-7, dual injection (Ongoing: monitor particulate emissions and ESP electrical conditions)
Extended Testing (Round 1a)	10/10/05–10/21/05	DARCO® Hg-LH throughout testing; Days 1–6: PRB, 4 lb/MMacf; upstream of field B-7 Days 7–8: PRB, 5 lb/MMacf; upstream of field B-7 Days 9–10: PRB, 5 lb/MMacf, OH + STM; upstream of field B-7 Days 11–12: PRB, 5 lb/MMacf; upstream of field B-7 (Ongoing: monitor particulate emissions and ESP electrical conditions)

[a] Sorbent injection location before ESP B-box field 5.
[b] Sorbent injection location before ESP B-box field 7.

Extended Testing (Round 1b)	10/22/05–11/08/05	DARCO® Hg-LH throughout testing; Days 1–3: PRB, 5 lb/MMacf; upstream of field B-5 Days 4–5: PRB, 5 lb/MMacf, OH + STM; upstream of field B-5 Days 6–8: PRB, 5 lb/MMacf; upstream of field B-5 Day 9: PRB, 5, 8 lb/MMacf; upstream of field B-5 Day 10: ColoWyo, 5 lb/MMacf; upstream of field B-5 Days 11–12: ColoWyo, 5 lb/MMacf, OH + STM; upstream of field B-5 Day 13: PRB, 5 lb/MMacf; upstream of field B-5 Days 14–17: PRB, 3 lb/MMacf; upstream of field B-5 Day 18: ColoWyo, 5 lb/MMacf; upstream of field B-5 (Ongoing: monitor particulate emissions and ESP electrical conditions)
Ash Recycle	11/09/05–11/13/05	Recycled DARCO® Hg-LH Days 1–2: ColoWyo Carbon/Ash 1 lb/MMacf; upstream of field B-5 Day 3: PRB Carbon/Ash 2 lb/MMacf; upstream of field B-5 Day 4: PRB Carbon/Ash 4 lb/MMacf; upstream of field B-5 Day 5: PRB Carbon/Ash 6 lb/MMacf; upstream of field B-5
Long-Term Testing (Extended)	11/16/05–03/10/06	DARCO® Hg-LH throughout testing; PRB, 4 lb/MMacf; upstream of field B-5
Parametric Testing (Redesigned Grid System)	01/16/07–01/18/07, 01/26/07	
Baseline (Round 3)	01/29/07–02/04/07	Mercury monitoring across test side of ESP B-box Particulate measurements collected at stack
Long-Term Testing (Redesigned Grid System)	02/05/07–03/07/07	DARCO® Hg-LH throughout testing; PRB, 5 lb/MMacf; upstream of field B-5 (Ongoing: monitor particulate emissions and ESP electrical conditions)

Because Independence is a load following plant, advance scheduling was required for the plant to respond to test requests for specific loads. Full load conditions were requested and granted for all Parametric and manual test periods. All Parametric and manual results reflect these steady-state, full-load conditions. Throughout most of the extended and Long-Term test sequence, Unit 2 operated without restrictions. Normal operation for Independence consisted of full load for the majority of the day from early spring to mid fall. During the evening hours, with the exception of exceptionally hot, humid days and nights, the plant would run at lower loads, but usually steady output. During the winter months, the full load times were less consistent, and the plant would make large load swings to respond to grid power demands. During the coldest days and nights in Arkansas, the plant operated at higher loading and steadier plant conditions in response to grid power needs. An exception occurred after Hurricane Rita struck in October 2005. The high voltage grid that Unit 2 supplied was essentially down as all the large power consumers on the Texas and Louisiana coast were shut down. Although Unit 1 continued running near full load, Unit 2 was limited to low load for several days in the middle of the initial Long-Term test sequence.

Sorbent Selection and Description

A key component of the planning process for these evaluations is identifying potential sorbents for testing. The budget and schedule for this test program allowed up to four different sorbents to be evaluated. These sorbents, and a brief description of each, are listed below:

- DARCO® Hg, a sorbent derived from a Texas lignite coal, is manufactured by NORIT Americas. This sorbent has been tested in various lab, pilot, and full-scale mercury control demonstrations and is considered the benchmark for performance comparisons. DARCO® Hg has a bulk density of 25–30 lb/scf.
- DARCO® Hg-LH, a sorbent derived from a Texas lignite coal and treated with bromine, is manufactured by NORIT Americas. DARCO® Hg-LH has been tested in a multi-site DOE/NETL program and was effective at increasing mercury capture compared to Baseline results at the test sites while firing PRB coal. It has physical characteristics similar to DARCO® Hg.
- DARCO® E-10 and DARCO® E-11, experimental sorbents derived from DARCO® Hg, were supplied by NORIT Americas. Their purpose is to minimize ESP reentrainment and particulate pass-through. The PAC in the E-10 is air classified and the PAC in E-11 is coarsely ground; two approaches that minimize fines production.

Sorbents were evaluated during Parametric testing against the following criteria. The first criterion was the ability of the sorbent to remove vapor-phase mercury from the flue gas stream across ESP B-box. The second criterion was the sorbent performance relative to its impact on balance-of-plant operating factors such as opacity and particulate emissions. A third criterion would apply if a bromine-treated sorbent was selected for Long-Term testing. In such a case, measurements would be made over the course of Long-Term testing to determine the additional release of halogens to the flue gas. Although a sorbent tested over the short term may yield different responses when used for long-term operation, it is likely that the comparative performance ranking of sorbents tested in the short term would be similar during long-term operation. As such, the sorbent with the best performance during the Parametric tests was selected for Long-Term testing.

Sample and Data Coordination

Collecting, analyzing, and archiving samples and plant operating data are key aspects of any field test program. A copy of the Sample Collection and Management Plan for the test program at Independence is included as Appendix F. Table 5 presents an example of samples and data collected during testing.

Table 5. Data collected during field-testing at Independence Unit 2.

Parameter	Sample/Signal/Test	Baseline	Parametric/ Long-Term
Coal	Batch sample	Yes	Yes
Coal	Plant signals: burn rate (lb/hr), quality (lb/MMBTU, % ash)	Yes	Yes
Fly Ash	Batch sample	Yes	Yes
Unit Operation	Plant signals: boiler load, etc.	Yes	Yes
Temperature	Plant signal at AH inlet and ESP inlet/outlet	Yes	Yes
Temperature	Full traverse at ESP inlet/outlet	Yes	No
Duct Gas Velocity	Full traverse at ESP inlet/outlet	Yes	No
Mercury (total and speciated)	Hg Monitors at ESP inlet/outlet	Yes	Yes
Mercury (total and speciated)	ASTM M6784-02 (Ontario Hydro) at ESP inlet/outlet	Yes (1 set)	No/Yes (3 sets)
HCl, HF, Br	EPA Method 26A at ESP inlet/outlet	Yes	Yes
Sorbent Injection Rate	PLC, lb/min	No	Yes
Plant CEM Data (NO_x, O_2, SO_2, CO)	Plant data—stack	Yes	Yes
Outlet Duct Particulate Mass	BHA CPM 5000: test and control ducts TEOM Series 7000: test duct	Yes Yes	Yes/Yes Yes/No
Stack Opacity	Plant data – Stack	Yes	Yes
Pollution Control Equipment	Plant data (Sec mA, Sec. Voltage, Sparks, etc.)	Yes	Yes

Various kinds of plant operating data were collected and made available immediately to the testing program via a workstation that the test team had connected to the plant control and information system. Grab samples of ash were collected from the ESP hoppers each day of testing and analyzed for mercury. A sketch of the ESP hopper configuration showing how the hoppers were numbered is presented in Figure 2. In the sketch, the first two rows of hoppers are on the test side of the ESP, the last two rows on the control side. Coal samples were batch sampled daily from the coal feed belt going to the coal bunkers and provided for analysis.

Baseline Testing (No Sorbent Injection)

Baseline testing began August 15, 2005. The following day, plant staff informed the test team that the outlet field on the test portion of the ESP B-box was non-operational and the second collection field on the test side of that box was operating at a reduced capacity. Because the first field at Independence collects the majority of fly ash (approximately 90%), reduced collection capacity later in the box would have minor impact on Baseline measurements. Hence, the Baseline testing was continued as planned though Friday, August 19, 2005. The Baseline data were used to characterize native mercury removal across the ESP in the absence of sorbent and to evaluate normal plant operating parameters. During the Baseline test period, Unit 2 was maintained at standard full-load conditions, about 880 MW, between the hours of 10:00 a.m. and 10:00 p.m.

A second round of Baseline testing began September 28 after the plant corrected the problems with TR B-7, the outlet electrical field on the test side of ESP B-box. Three days of tests were conducted to re-establish the unit's mercury and particulate Baseline measurements and native mercury removal. Throughout the Baseline test periods, mercury measurements were made at the ESP inlet and outlet with the mercury S-CEMs. During three days of the first round of Baseline testing, several manual measurements were also conducted at the inlet and outlet of the ESP, including the following (Appendix D1):

- ASTM M6784-02 Ontario Hydro Method (Speciated Mercury)
- STM, based in part, on the method described in 40 CFR Part 75 Appendix K (previously EPA draft Method 324); taken at outlet only
- EPA M17 (Particulate Concentrations)
- EPA M26A (Halogen and Hydrogen Halide Concentrations)

Because of the influence of HBr, HCl, and HF on sorbent effectiveness, HBr, HCl, and HF measurements (Method 26A) were made at the same time the Ontario Hydro samples were collected to better characterize the flue gas. The outlet particulate emissions are a key parameter to assess the impact of carbon injection on ESP performance. Therefore, particulate emission measurements were made with EPA Method 17 at both the ESP inlet and outlet.

During the extended test portion of the program, a third round of Baseline testing was conducted from January 29, 2007, to February 4, 2007. A single S-CEM mercury monitor was used to measure total vapor-phase mercury at the inlet and outlet test ducts of the ESP B-box. Particulate measurements were collected from the stack during this Baseline period.

Parametric Testing

Parametric tests were conducted at Independence Unit 2 to evaluate the TOXECON II™ process using four PAC sorbents: DARCO® Hg, DARCO® Hg-LH, and two experimental DARCO® sorbents, DARCO® E-10 and DARCO® E-11. Each of these sorbents was injected at different concentrations to determine mercury removal effectiveness and to characterize sorbent impact on plant operation on a short-term test basis. During the Parametric test period, Unit 2 was maintained at standard full-load conditions, about 880 MW, between the hours of 10:00 a.m. and 10:00 p.m.

As mentioned above, during the initial Baseline testing period, the plant reported that the test side of ESP B-box had problems with two electrical fields: B-3 and B-7. Field B-3 was operating at reduced or shutoff power levels. This field had operated at a reduced capacity well before the testing started, and previous efforts to recover the field had not been successful. Reduced power on this field meant a slight increase in the amount of fly ash that would go to the next field, B-5. This impact was not considered significant enough to modify test protocol.

The other problem electrical field, ESP B-7, was non-operational. This problem was of concern for two reasons. First, sorbent injection would be limited to the mid-box location because the rear injection grid was positioned directly before field B-7. Second, injection at the mid-box location would correspond to an effective SCA of 135 ft^2/kacfm, rather than the anticipated SCA of 270 ft^2/kacfm that would be available if B-7 were operational. Consequently, the test team decided to carry out an abbreviated Parametric test sequence (round 1) using a single injection location with a reduced SCA. Once field B-7 was again operational, the full testing sequence was rescheduled and Parametric testing was resumed (round 2).

Stages 1 and 2

The first stage of Parametric testing was conducted from August 22–25, 2005. The portable sorbent delivery system was used throughout this test sequence. During the first round of Parametric testing, there was an increase in opacity spikes during ESP raps that appeared related to injecting DARCO® Hg and Hg-LH under some conditions. To verify these results, these two sorbents were retested on September 8–9, 2005, (one day for each sorbent) and opacity measurements taken.

The second sequence of Parametric tests ran from October 1–8, 2005. All four of the original PAC sorbents were evaluated in various combinations of injection rates and injection fields. During this sequence of tests, TR set B-3 failed to an “Off” status. From this point on, the plant ran TR set B-3 on an “as available” basis.

The portable sorbent delivery system was used for the first six days of the second stage of Parametric testing. The final two days of testing included the use of both injection locations simultaneously, a procedure that required the capabilities of two feeders and blowers. Because the Porta-PAC system is a single feeder and blower arrangement, the silo delivery system was used during these days to deliver DARCO® Hg-LH.

Follow-On Stage

During the extended test portion of the program, a third stage of Parametric testing was conducted from January 16–18, 2007, with repeat tests conducted on January 26, 2007 (Appendix A4). The tests were aimed at evaluating the redesigned injection grid and delivery system. Mercury measurements were conducted with the single S-CEM configuration. No particulate testing was performed during this round of testing.

Long-Term Testing

Long-Term testing of the TOXECON II™ system at Independence Unit 2 followed the second round of Parametric testing, commencing on October 10, 2005, and continuing without interruption until November 9, 2005. A single PAC, DARCO® Hg-LH, was selected based on its performance during the Parametric tests for further evaluation. Twice during this time period, the plant shifted from burning PRB to 3-day test burns of western bituminous ColoWyo coal. During the Long-Term testing period, three sets of Ontario Hydro, M17, and M26A measurements were conducted at the inlet and outlet of the ESP along with STM measurements (Appendices D2–4).

Long-Term testing was conducted at settings determined by the Parametric tests and approved by the DOE and Entergy Independence. The DOE intended that these settings represent the most cost-effective conditions for a moderate level of mercury control (i.e., 30–60%). To achieve the highest possible level of mercury removal would require higher concentrations of sorbent and thus increase program costs, but such a goal would best test the performance boundaries of the TOXECON II™ injection system and allow a stronger assessment of its balance-of-plant impacts. Deciding upon test settings was also influenced by the current (2005) federal and state regulatory environment: some states are now legislating very high removal rates for coal-fired plants, on the order of 80 to 90%. To assess the feasibility of testing at a higher sorbent concentration, the costs were reviewed and it was determined that the increased sorbent cost would remain within the budget of the test program. Consequently, the decision was made to choose settings that would evaluate the system limits.

This initial Long-Term test period was divided into two phases. The first phase lasted 12 days. Initially, 4 lb/MMacf of sorbent was continuously injected in the rear injection grid—i.e., directly upstream of ESP B-box field B-7. Because the mercury removal rate was less than expected during the first half of this round, the sorbent concentration was increased to 5 lb/MMacf for the remainder of the round. In addition to gathering data on mercury removal, the objective of this test phase was to determine the effects of PAC injection on opacity and particulate pass through when using a relatively small ESP collection area (effective SCA = 135 ft^2/kacfm) downstream of the injection point.

The second phase of Long-Term testing immediately followed the first and lasted for 18 days. During the second round, the injection location was changed to the mid-box injection grid (i.e., directly upstream of ESP B-box field B-5) and injection concentrations were maintained at approximately 5 lb/MMacf, with several test runs at higher and lower injection concentrations to test several key parameters. During these individual test periods, several hours in duration each, the injection concentration varied from 1 to 8 lb/MMacf. Data gathered under these conditions could be used to verify Parametric test results that indicated PAC injection with a mid-sized collection area (SCA = 270 ft^2/kacfm) is slightly more effective than with a smaller one. Moreover, it could be expected that injecting upstream of the larger collection area would have less of an impact on particulate emissions and opacity than that observed during the first round. A drawback to injecting in the upstream field meant that the final two hopper rows would have to be segregated for ash recycle and disposal. To better evaluate the TOXECON II™ system, this round of Long-Term testing involved several objectives that included the following: to obtain data on mercury removal efficiency, to determine the effects on ESP operation, to determine the effects on combustion byproducts, to evaluate the impacts to the balance-of-plant equipment, and to determine the process economics.

Immediately following the Long-Term tests, an ash/carbon recycle test was performed. Shortly after the ash recycle tests ended, a Long-Term operational demonstration commenced. Testing of DARCO® Hg-LH continued on a near continuous basis for two periods: the end of November through most of December 2005 and then from late January to early March 2006. During these periods, injection occurred at various rates and injection locations using the initial injection grid design.

The redesigned injection grid and delivery system was evaluated under Long-Term conditions from February 6 through March 7, 2007. Mercury measurements were conducted with a single S-CEM measuring total vapor phase mercury across the inlet and outlet ducts of the test side of ESP B. Particulate testing was conducted both at the stack and on the test and control side of the west ESP B-box outlet duct.

Ash Recycle Testing

As a separate part of the overall program, a short ash/carbon recycle test was conducted from November 9–13, 2005. Approximately 18,000 lbs of ash/sorbent mixture collected during the Parametric and Long-Term testing period from the hoppers downstream of the ESP B-box injection locations was transferred to the test injection silo. The mixture was injected into the injection grid placed before B-box field B-5 at an average concentration of 1 lb/MMacf (PAC equivalent). During the first two days of this testing, the plant burned ColoWyo coal, then switched back to PRB on the third day. Grid injection ceased on November 13 because the injection grid appeared to be plugged. The ash/sorbent mixture remaining in the silo was then injected through two of the inlet ports on the test side of the ESP B-box, one on either side of the splitter in the inlet duct. This procedure allowed data to be gathered on the effectiveness of the ash/sorbent mixture on mercury removal in a pre-ESP injection configuration.

RESULTS FROM INDEPENDENCE TESTING

The initial field-testing program of the TOXECON II™ system at Independence was divided into three periods: Baseline, Parametric, and Long-Term (Appendix A1). During Baseline testing, no sorbent was injected into the ESP. During Parametric testing, the mercury removal performance of four sorbents was evaluated. During Long-Term testing, the performance of one sorbent was evaluated during a 30-day continuous injection period. Results from each test series are included in this section. The program was extended to include modeling of the sorbent injection grid and subsequent redesign of the grid and delivery system. Results from the modeling efforts and field-testing of the redesigned grid system are included here, too. Ash/carbon recycling tests were also conducted as part of the initial field test program and the results are presented below.

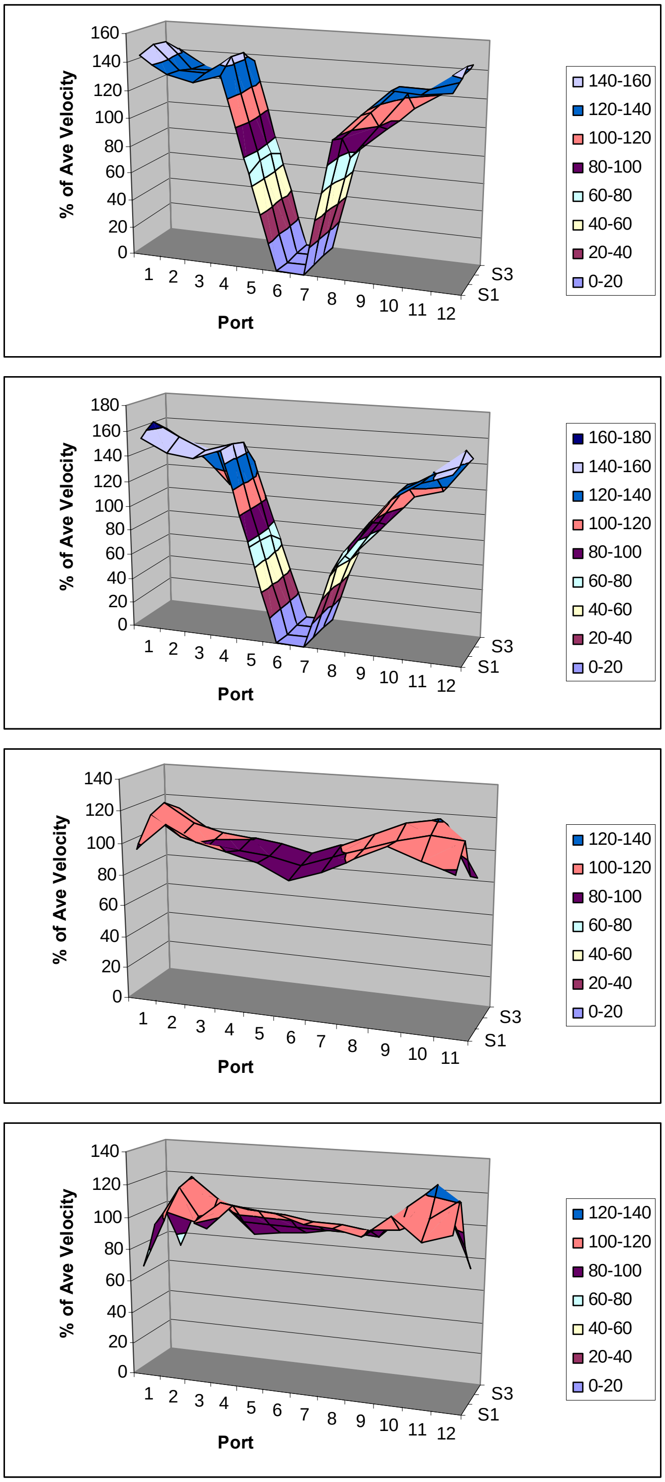
Velocity and Temperature Profiles

Prior to the Baseline test sequence, equipment set-up, installation, and operational check-out were performed. One of the preliminary tests performed was a velocity profile of the inlet and outlet ducts of the test side of the ESP B-box. The design premise of the TOXECON II™ injection system installed at Independence was that the flue gas flow would be relatively uniform. The design of the injection grid was intended to provide an even distribution of sorbent from top to bottom and side to side. S-CEM extraction probe locations were identified based on the preliminary velocity traversal measurements.

When the series of Ontario Hydro/M17/M26A tests were conducted during the August 2005 Baseline and late October 2005 Long-Term tests, velocity and temperature traverses were performed along the test inlet and outlet ducts of ESP B. Six runs of pressure differentials, as determined by a pitot tube, and temperatures were measured at four depths from 8 of the 12 ports during both the Baseline and Long-Term test period. (Further details are provided in the METCO reports included in Appendices D1–4.) Because the boiler load was high (> 750 MW) during each run, the data values were averaged for each sample point during both test periods. Plots of the velocity profiles are given in Figure 16. Velocity (fpm) was calculated at each sample point using the following equation:

$$V = 60xC_p\sqrt{\frac{2g\times\rho_{man}\times P_{std}\times MW_{air}\times\left(T_d+460\right)\times\Delta P}{12\times\rho_{air}\times P_d\times MW\times\left(T_{std}+460\right)}}$$

Where	$C_p =$		Pitot Tube Calibration Factor
	$g =$	32.174 ft/sec^2	Acceleration of gravity
	$\rho_{man} =$	62.32 lb/ft^3	Density of manometer oil
	$P_{std} =$	29.92”H_2O	Standard Pressure
	$MW_{air} =$	28.96 lb/lb-mole	Molecular Weight of air
	$T_d =$	º F	Duct Temperature
	$\Delta P =$		Differential Pressure
	$\rho_{air} =$	0.0752 lb/ft^3	Density of air
	$P_d =$	” H_2O	Duct Pressure
	$MW =$	lb/lb-mole	Molecular Weight of duct gas
	$T_{std} =$	68º F	Standard Temperature



(a) Vav = 3100 fpm

(b) Vav = 2850 fpm

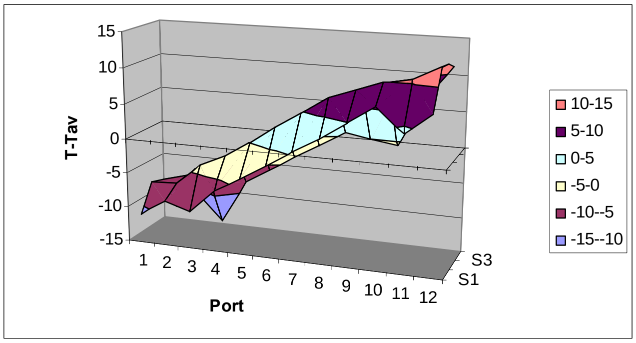
(c) Vav = 2900 fpm

(d) Vav = 3000 fpm

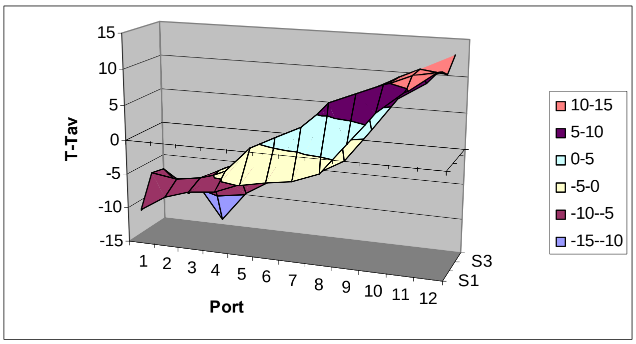
Figure 16. ESP duct velocity profile expressed as Percentage of Average Velocity (Vav).
(a) Inlet: Baseline 2005. (Velocity values at Ports 9 and 5 are interpolated.)
(b) Inlet: Long-Term 2005. (Velocity values at Ports 9 and 5 are interpolated.)
(c) Outlet: Baseline 2005. (Velocity values at Ports 4–6 and Port 9 are interpolated.)
(d) Outlet: Long-Term 2005. (Velocity values for Ports 5–8 are interpolated.)

The general shapes of the of the inlet and outlet velocity profiles are similar for both the test periods. The asymmetry of the inlet profile around the internal divider may partially be an artifact as the values at the (nonexistent) port 5 were interpolated. As expected, the average velocity at the outlet of the ESP is less than that of the inlet during Baseline testing. The increase in average velocity at the outlet relative to the inlet during the Long-Term tests may be an artifact as the values for the midsection (ports 5–8) were interpolated and may be high. Moreover, results from the physical modeling of the outlet duct suggest that the midsection of the outlet duct would not exhibit the fairly flat profile as shown here. The ESP duct configuration may also have influenced the results. The ports in the inlet duct were located 2.61 equivalent duct diameters (edd) downstream from a bend and 0.67 edd upstream from an expansion whereas the ports in the outlet duct were located 0.71 edd downstream from a constriction and 0.33 edd upstream from a bend.

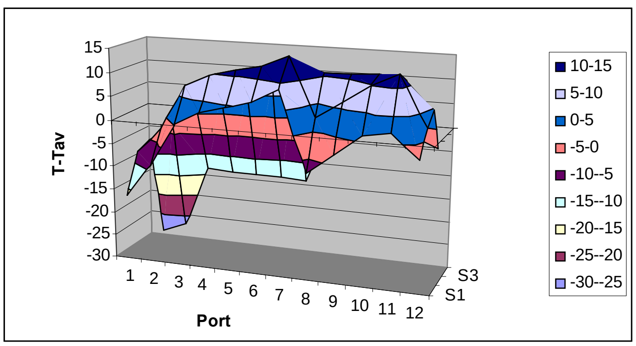
Temperature profiles of the test inlet and outlet ducts of the ESP B-box during the August 2005 Baseline and late October 2005 Long-Term tests are shown in Figure 17. As can be seen in the figure, there is a temperature gradient of approximately 20º along the length of the inlet duct. Although a gradient is still apparent (and more pronounced) in the Long-Term profile of the outlet duct, such a gradient is not apparent in the profile of the outlet duct for the Baseline test. The average temperature at the outlet duct was slightly higher than that of the inlet duct during the Long-Term testing period. This may be an artifact as the values at the mid section of all four profiles were interpolated.



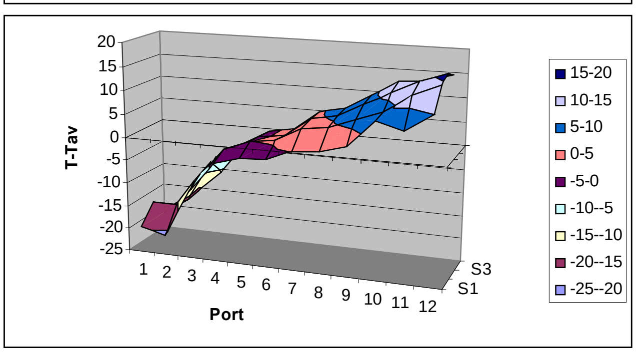
(a) Tav = 324 ºF



(b) Tav = 312 ºF



(c) Tav = 323 ºF



(d) Tav = 314 ºF

Figure 17. ESP duct temperature profile.
Values are the differences between the average temperature at a given sample point (T) and the average of the duct (Tav).
(a) Inlet: Baseline 2005. (Temperature values at port 9 and from ports 7–5 are interpolated.)
(b) Inlet: Long -Term 2005. (Temperature values at port 9 and ports 7–5 are interpolated.)
(c) Outlet: Baseline 2005. (Temperature values at ports 4–6 and port 9 are interpolated.)
(d) Outlet: Long-Term 2005. (Temperature values at ports 5–8 are interpolated.)

Baseline Mercury Removal

Four rounds of Baseline tests (no sorbent injection) were conducted: (1) August 15–21, 2005; (2) September 28–30, 2005; and (3) January 15, 2007, and then January 29, 2007, through February 4, 2007. Prior to the first round of tests, some data were also gathered from August 6–14, 2005. Several different methods were used to measure mercury at Independence. These included flue gas measurements using the STM, Ontario Hydro (OH), mercury analyzers (S-CEM), and analysis of mercury in coal and ash samples. Results from the latter two are presented later in this report. During the first round of Baseline tests, three Ontario Hydro runs were conducted across the ESP B-box. S-CEM and (ESP outlet) STM data were collected concurrently with the Ontario Hydro runs. The results of these three methods for the level of mercury (corrected to 3% O_2) at the outlet of ESP B-box are presented in Table 6. The full Ontario Hydro test reports are included in Appendix D. Recall that the Ontario Hydro method is a measure of total mercury (elemental, oxidized, and particulate) while S-CEM and STM provide a measure of total vapor-phase mercury. Because the presence of fly ash can significantly affect mercury speciation, the Ontario Hydro method has the potential for sampling bias. Such potential is lower with the S-CEM and STM because these approaches minimize ash-vapor contact.

Table 6. Comparison of ESP B-box outlet Hg levels obtained by different methods during 2005 Baseline OH runs.

August 17–18, 2005	OH (μg/dNm^3)	S-CEM (μg/dNm^3)	STM (μg/dNm^3)
Run 1	16.48	9.7	12.7
Run 2	10.60	9.4	11.4
Run 3	8.75	9.4	13.5

OH is Hg^{2+} + Hg^0; S-CEM and STM are total vapor-phase mercury.

The average total vapor-phase mercury concentrations (corrected to 3% O_2) at the inlet and outlet of the ESP B-box during the pre-Baseline and Baseline August test period are shown in Figure 18. As expected at a PRB plant using a cold side ESP for particulate control, the native removal capability is very low. The average removal efficiency measured with the S-CEMs during the first two rounds of Baseline testing was typically very low. Often during load changes, the outlet mercury concentration spiked above the inlet concentrations as measured by the SCEM. The Ontario Hydro results (taken during the first round of testing) showed an average removal efficiency of 12.2%. During these tests, the inlet SCEM was reading slightly higher than the outlet when corrected to 3% O_2. Problems encountered with adjusting the S-CEMs during August may partially account for much of the variability observed in levels of mercury across the ESP and the particularly low removal level measured as the average removal for the September round of tests was 2%.

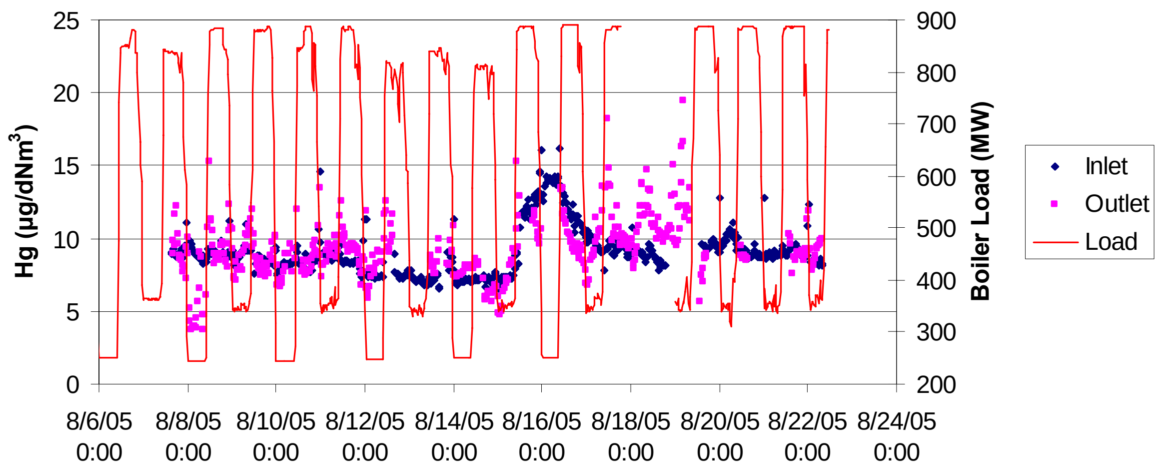


Figure 18. Average 30-minute total vapor-phase mercury concentrations for 2005 pre-Baseline and Baseline test period.

Figure 19 shows the average mercury measured at the inlet and outlet of the ESP during the Baseline testing runs with the three measurement methods. All results are converted to dry normal and corrected to 3% O_2.

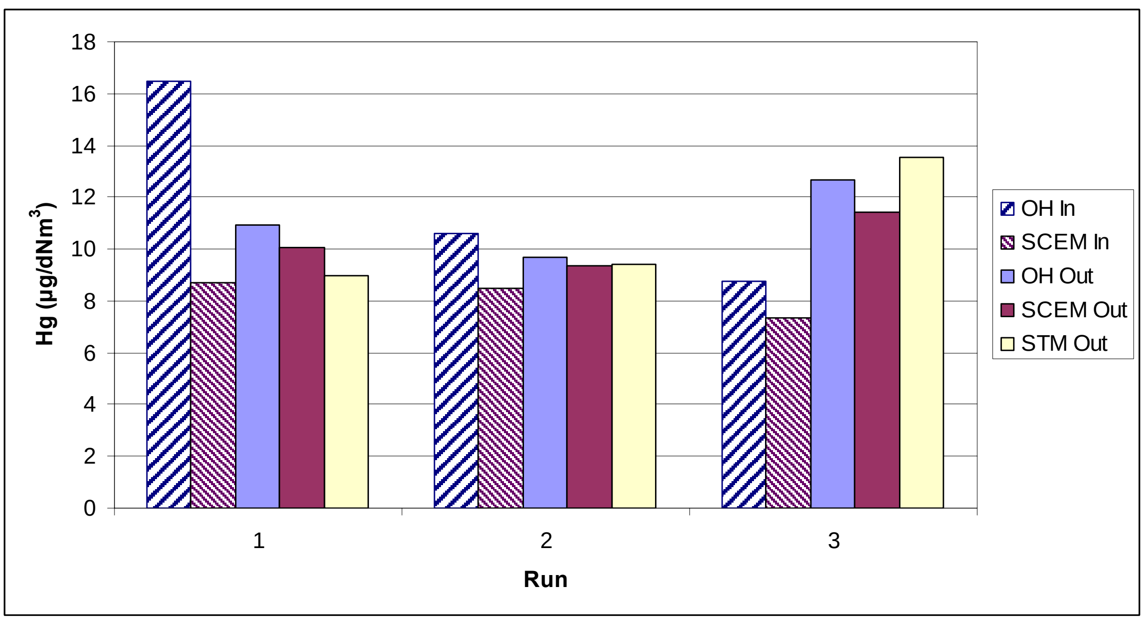


Figure 19. Average total mercury at the inlet and outlet of the ESP B-box during 2005 Baseline testing.

Of interest during the Baseline testing was the speciation of vapor-phase mercury across the ESP B-box test side. While total vapor-phase mercury numbers vary little, the percentage of elemental drops from an average of 80% at the inlet to ESP to less than 50% at the outlet of the ESP. As can be seen in Figure 20, this magnitude of change in speciation is consistent for the Baseline test series independent of unit load. The increased fraction of oxidized mercury could be associated with both the large SCA for the Independence ESP and potential intermittent back corona. UV resulting from back corona in the electrical field could cause oxidation of the elemental mercury. For reference, the averaged percent elemental mercury ($Hg^0/(Hg^{2+} + Hg^0)$) at the inlet and outlet as determined by the OH tests during Baseline are also shown in Figure 20. As can be seen, the OH results did not show as marked a difference in the percent of elemental mercury at the inlet and outlet of the ESP as the S-CEM did. This may indicate a sampling artifact from the S-CEMs.

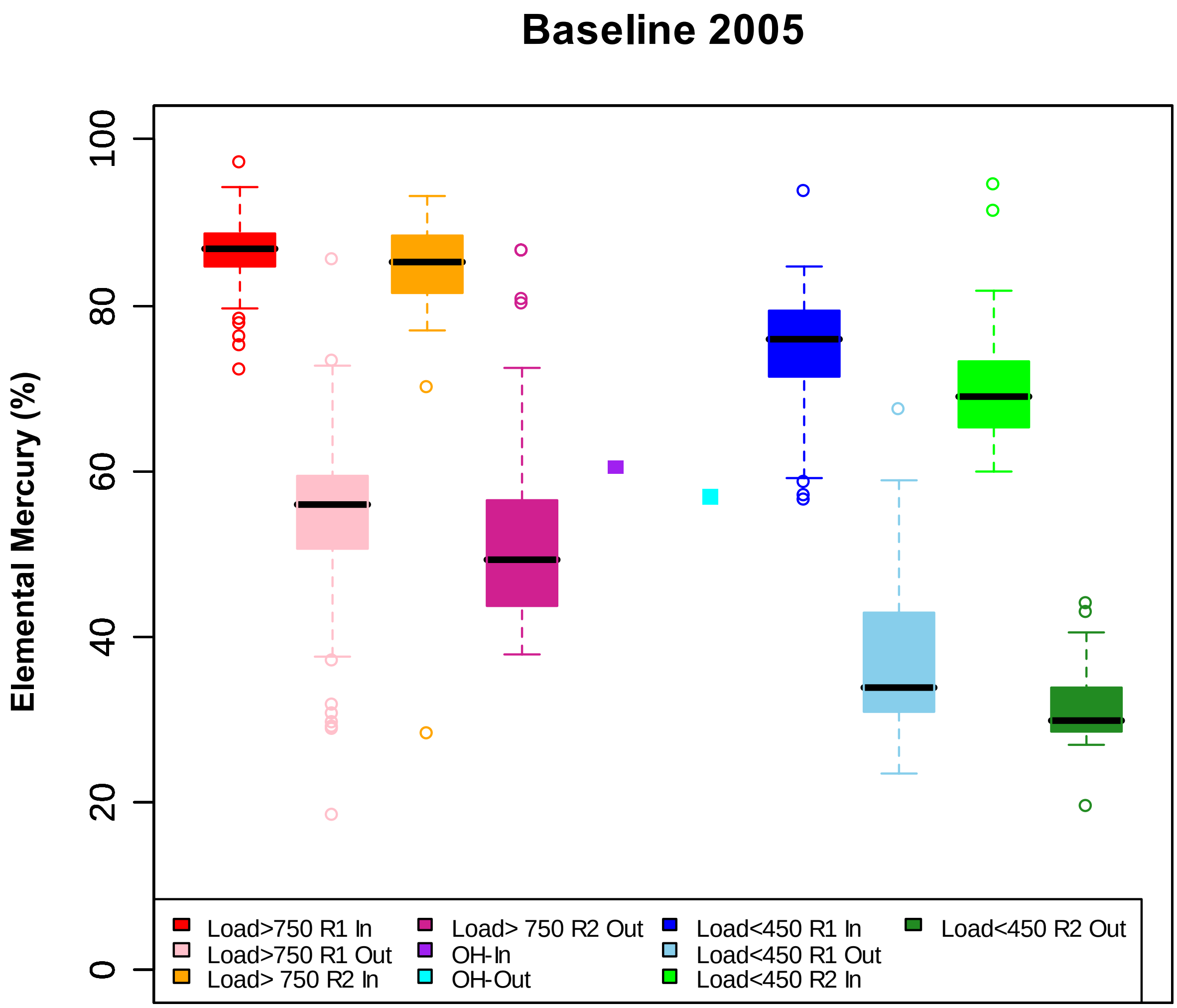


Figure 20. Fraction of elemental mercury across the ESP B-box during 2005 Baseline testing.

The average mercury concentration in the flue gas during the 2007 Baseline level given by the S-CEM was slightly lower than that observed during the 2005 Baseline tests; however, the average removal efficiency remained quite low (see Table 7 and Figure 21). As shown in Figure 21, the boiler load remained high during the last few days of January which corresponded to a period of cold ambient temperatures. Lower mercury concentrations from the afternoon of the January 29 through midday on the January 30 indicate a period when the plant was firing ColoWyo coal.

Table 7. Average total vapor-phase mercury across the ESP B-box during 2007 Baseline testing. Values corrected to 3% O_2.

ESP Inlet Hg (μg/dNm^3)	ESP Outlet Hg (μg/dNm^3)	Removal Efficiency (%)
7.1 ± 1.9	6.5 ± 2.0	3.4 ± 23.1

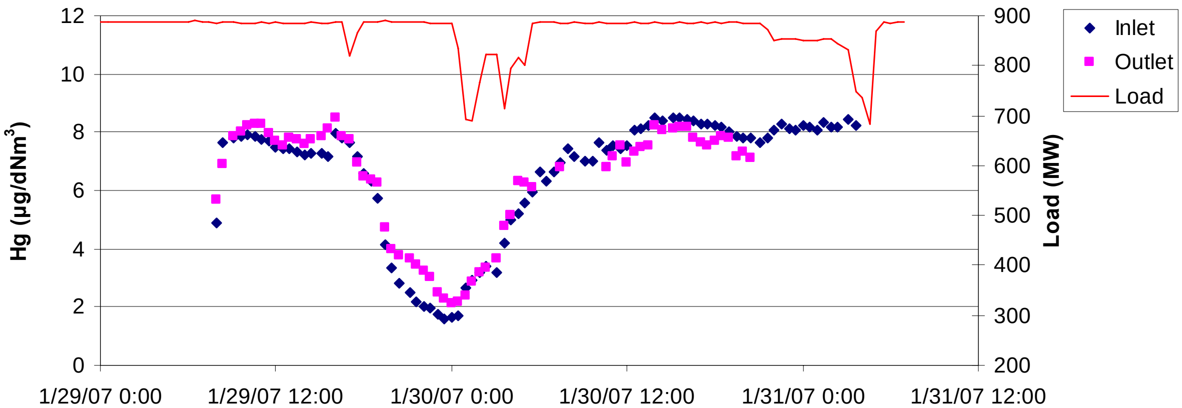


Figure 21. Trend plot of average total vapor-phase mercury across the ESP B-box during 2007 Baseline tests. Values corrected to 3% O_2.

Parametric Mercury Removal

Parametric testing to evaluate the performance of four different sorbents was undertaken in three stages. The first stage was conducted in late August 2005 with the ESP outlet field, T/R field B-7, out of service. This stage was followed by a two-day set of limited tests in early September 2005 to confirm particulate/opacity readings from the first stage of testing. A complete series of Parametric testing following the original test plan scheme was completed in early October 2005 when field B-7 was again in service. During testing, the varying power levels for field B-3 had no correlation with varying vapor-phase mercury removal trends.

When it became apparent that the original PAC delivery and injection system did not provide sufficient PAC distribution, the system was redesigned. After the redesigned injection grid was constructed, a final stage of Parametric tests was completed in January 2007. The results from these various stages of testing follow.

<u>Stage I</u>

As mentioned previously, ESP TR field set B-3 was operating at reduced or shutoff power levels and field B-7 was non-operational during the first stage of Parametric testing (August 21–25, 2005). Consequently, sorbent was injected mid-box (i.e., between fields B-3 and B-5). Figure 22 shows box-whisker plots of the average total vapor-phase mercury removal efficiency of the four different test sorbents at various injection concentrations during August 2005.

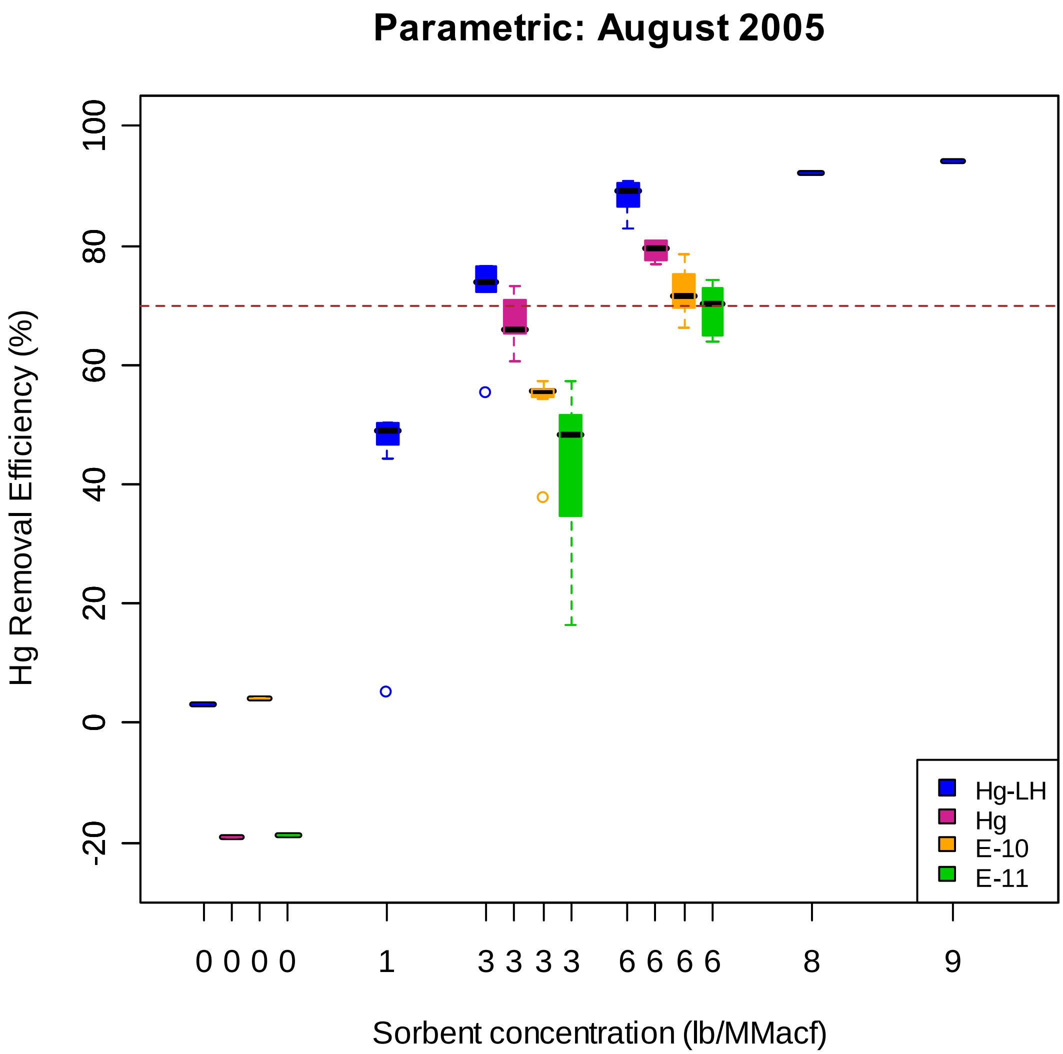


Figure 22. Comparison of sorbent performance during the first stage of Parametric tests. Midbox injection, field B-7 down, field B-3 low/no power. Dashed line at 70%.

During this round of tests, readings of elemental mercury were also taken. The average percentage of elemental mercury relative to the total vapor-phase mercury at the inlet and outlet of the test side of ESP B for each of the test sorbents is shown as box-whisker plots in Figure 23. The S-CEMs recorded a decrease in the fraction of elemental mercury across the ESP prior to injection and for each sorbent at each injection concentration. In addition, injecting non-bromine treated sorbents resulted in an increase in the fraction of elemental mercury measured at the outlet of the ESP as the concentration of sorbent increased. This suggests that the non-bromine treated sorbents are more effective at removing oxidized mercury than elemental mercury. The fraction of elemental mercury measured at the outlet of the ESP during DARCO® Hg-LH injection, the only bromine-treated PAC tested during this period, concentration did not vary significantly with sorbent concentration. This suggests that DARCO® Hg-LH was equally effective at removing both elemental and oxidized mercury. None of the sorbents demonstrated an increase in the fraction of oxidized mercury across the ESP as has been observed at other sites.

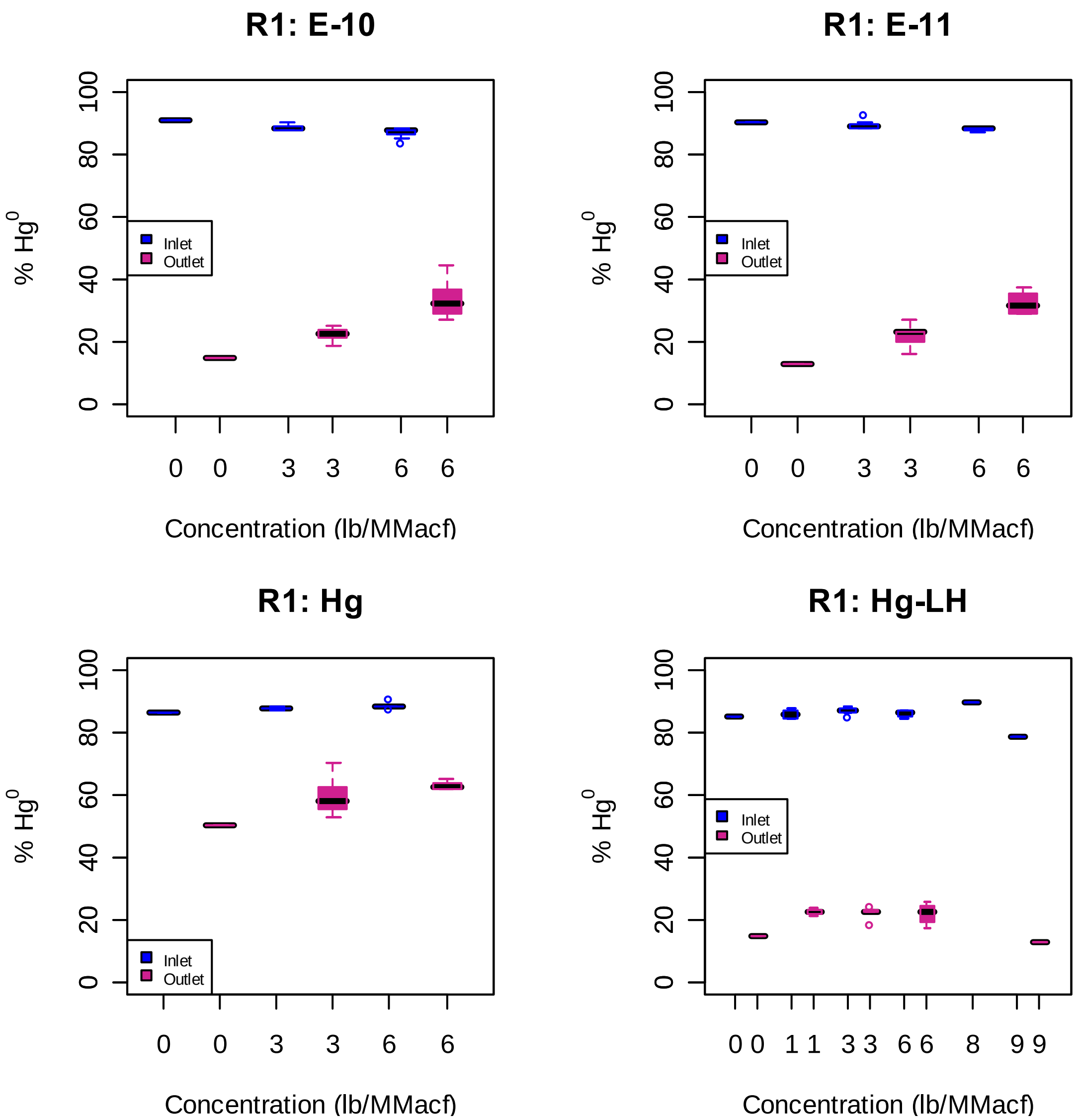


Figure 23. Average percentage of elemental mercury across the test side of ESP B during the first stage of Parametric tests (August 2005). ESP field B-7 non-operational; mid-box injection.

An unscheduled outage in late September 2005 allowed the plant to repair field B-7. The cause appeared to be a discharge electrode wire that was shorting to the collector plate. During this outage, ADA-ES was on site to perform a visual inspection of the injection grid. Access to the grids included the upper and lower sections of the field B-7 grid and the lower sections of the field B-5 grid. Internally, the vertical lances appeared to be clean, with the lower injection ports being clean and free of any material. There was some build up of ash on the leading and trailing edges of the injection lances, but the lance sides perpendicular to the flue gas flow, where the injection ports are located, were clean. PAC deposits on the collection plates were evident on the lower sections of the trailing edge of field B-5 and the leading edge of field B-7. There were no evident deposits of PAC in the higher section of the field B-7 grid or in the space between ESP fields B-3 and B-5, where the field B-5 injection grid is located.

Physical tracing of the injection supply lines confirmed that the injection during the initial Parametric tests occurred through the field B-5 injection grid. Although the PAC deposits on the ESP collection plates were not evenly spaced, factors other than the actual grid injection system could impact the PAC deposition pattern. For example, the effects of gravity on the PAC could account for the absence of PAC high in the field B-7 spacing. As the PAC drifts further downstream from the injection point, the natural tendency of the PAC at the low air velocity in the ESP, less than 3.3 fps, would be to trend down. The reduced carrying capacity in the ESP relative to the flue gas stream in the ducts (usually greater than 50 fps) is inherent in its design such that fly ash and re-entrained material will drop into the ESP collection hoppers.

Based on the visual inspection, the performance during the first Parametric testing and using the previous TOXECON II™ system results as a guide, there was little evidence to suggest any issues with PAC distribution at this time in testing.

Stage II

Parametric tests were continued after ESP field B-7 was repaired. The test sorbents were injected in the rear of the ESP B-box, between fields B-5 and B-7, and their performance evaluated at different concentration levels. From this stage onwards, readings of mercury levels across both the test and control side of ESP B-box were taken (total vapor-phase mercury only). All inlet S-CEM mercury measurements were taken on the vertical duct on the ESP B test side. Outlet mercury measurements were taken on the vertical outlet ducts on both the control side and test side of ESP B. Monitoring the control side outlet gave a continuing verification of the native removal without PAC injection.

Figure 24 shows box-whisker plots of 30-minute averages of mercury removal efficiency for the test sorbents at various concentrations during the second stage of Parametric tests (October 1–7, 2005). The corresponding averages across control side of the ESP are also indicated. The results from one day (October 8, 2005) of sorbent injection to both the mid and rear ESP box locations are given in Figure 25. As can be seen in these figures, there is some evidence of PAC appearing to impact the control-side mercury measurement, particularly at high injection concentrations.

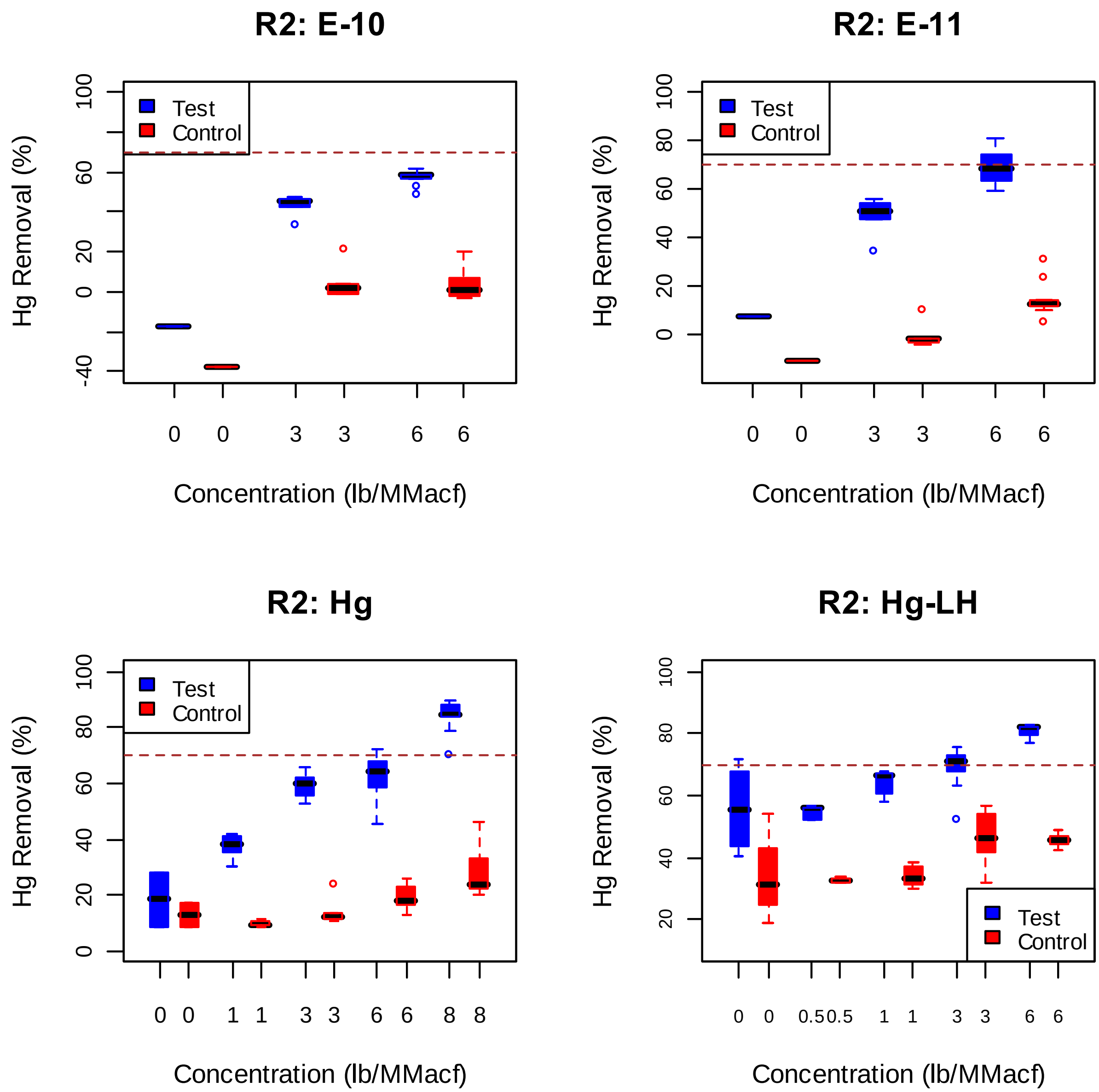


Figure 24. Average mercury removal efficiency for test sorbents at various injection concentrations across the test side and control side of ESP B-box during the second stage of Parametric tests (October 2005). ESP field B-7 operational; rear box injection.

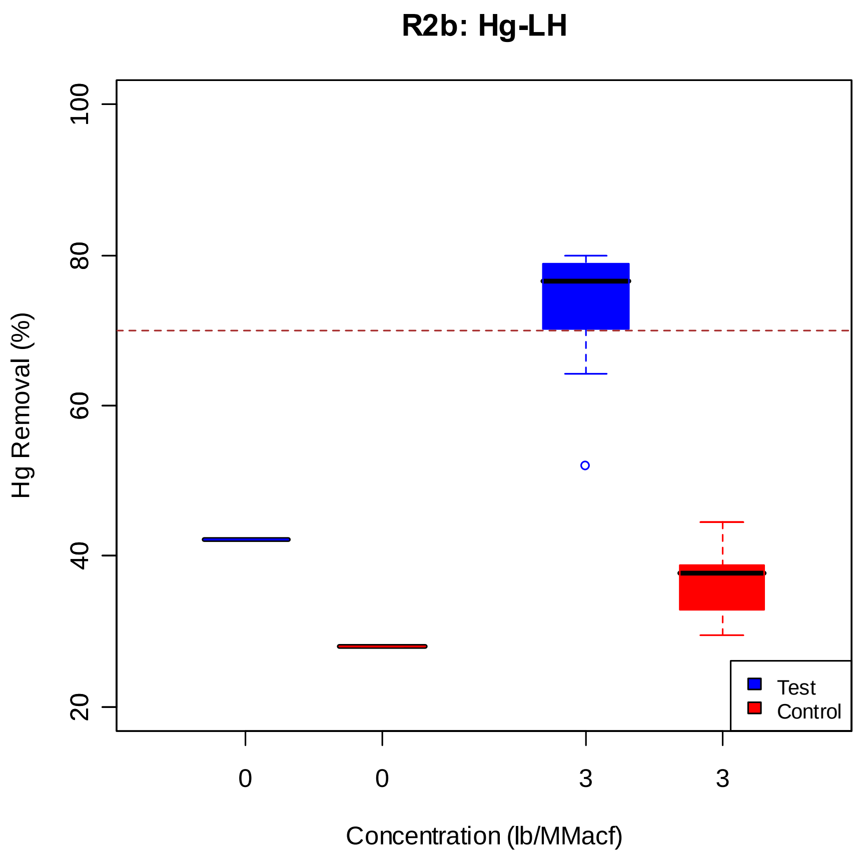


Figure 25. Average mercury removal efficiency for test sorbent DARCO® Hg-LH at single injection concentration across the test side and control side of ESP B-box during the second stage of Parametric tests (October 2005). ESP field B-7 operational; dual injection to both mid and rear box.

The final stage of Parametric testing in 2005 involved only a single sorbent, DARCO® Hg-LH. Before looking at the results from that stage, it is worth noting that the results from the first two stages of Parametric testing indicate that a particular sorbent, its concentration, and the injection location impact mercury removal efficiency across the ESP. Several comments on the comparative performance of the sorbents follow.

NORIT's DARCO® Hg-LH compared favorably to the benchmark test sorbent, DARCO® Hg, and its derivatives, Hg E-10 and E-11. The two derivatives of DARCO® Hg are test products designed to study the impacts of particle sizing on particulate pass through and opacity. The two products were not designed to enhance the mercury removal capability of DARCO® Hg. Specifically, NORIT predicted prior to testing that the two derivative PAC materials would not perform as well as the Baseline DARCO® Hg. The validity of this prediction can be seen in Figure 22 and Figure 24.

Although DARCO® Hg-LH exhibited higher mercury removal efficiency than DARCO® Hg, its relative performance was not as favorable as expected for a site firing a PRB coal and configured with an ESP Performance limitations resulting from poor sorbent distribution may have limited the relative difference between the sorbents, as will be discussed later.

In general, sorbents performed better when injected at the ESP mid-box location and in higher concentrations. An exception was the injection of DARCO® Hg-LH at low concentrations (0.5 to 1 lb/MMacf), when injection in the rear-box grid outperforms injection in the mid-box (65.5% vs. 43.4%). Similarly, injection of DARCO® E-11 at a concentration of 3 lb/MMacf in the rear-box grid showed a slight improvement in performance over the mid-box location (48.9% vs. 43.7%). When DARCO® Hg-LH was injected simultaneously in both the mid-box and rear-box locations at 3 lb/MMacf, it performed slightly better than either the mid-box or rear-box only injections at the same concentration (73.1% vs. 71.3% and 68.8%, respectively), but this performance was still lower than when it was injected at higher concentrations in either the mid-box or rear-box locations.

During the second stage of Parametric tests, relatively high levels of native mercury removal were observed directly prior to injecting DARCO® Hg and also DARCO® Hg-LH (see Figure 24 and Figure 25). As with all Parametric testing, one potential pitfall of the test results was a failure to allow proper time for the system to reestablish baseline conditions prior to attempting to establish a new sorbent trend data point. Residual effects from the previous day's Parametric run may partially account for the unusually high levels of mercury removal in the absence of sorbent injection and may also have influenced the relatively high performance observed at low injection concentrations.

Stage III

The third stage of Parametric testing was conducted in 2007 from January 16 through January 18, with repeat tests conducted on January 26 using DARCO® Hg-LH and a redesigned injection grid. The results indicate that the new lance design and conveying system were an improvement from the original lance design. Mercury removal was measured at three different carrier air flow settings through the lances: modeled flow based on laboratory test results, 36% more carrier air flow than modeled, and 27% less air flow than modeled. No significant difference in the mercury removal results was noted at these flows, as shown in Figure 26. However, some degradation in performance was noted when the tests were repeated a week later. This was a precursor of the operational difficulties encountered during 2007 Long-Term testing and discussed in the next section.

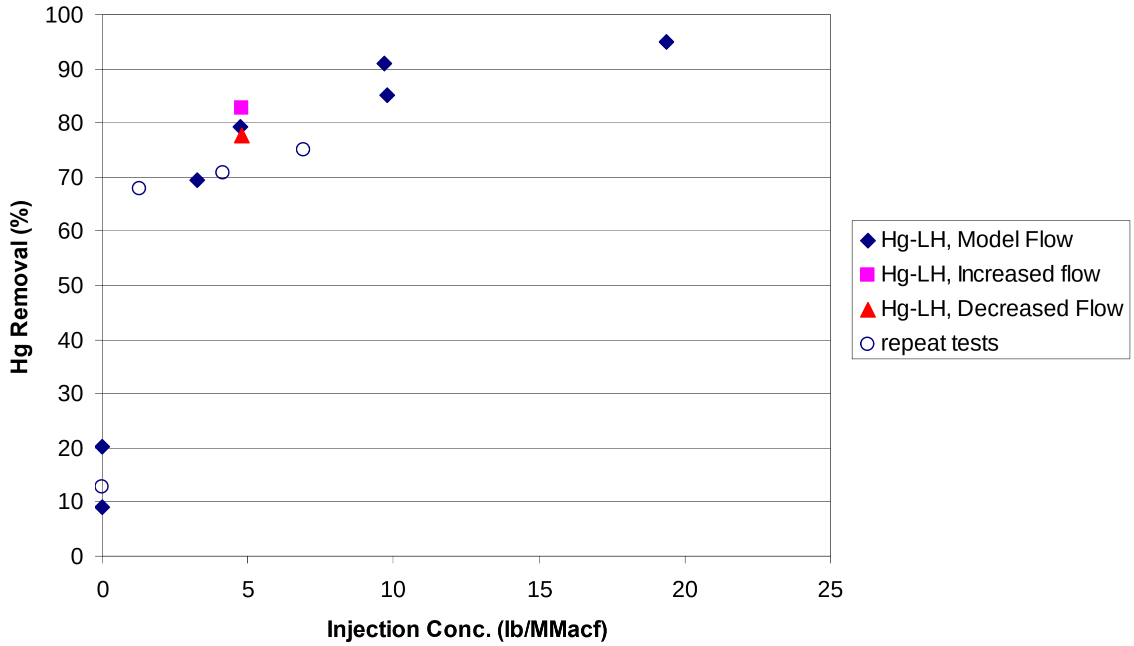


Figure 26. Mercury removal efficiency of Hg-LH during 2007 Parametric tests and using redesigned lances.

Long-Term Mercury Removal

Based on the slightly better removal rates for the DARCO® Hg-LH, minimal opacity spiking during ESP plate rapping, and discussions with other project participants, DARCO® Hg-LH was chosen for the Long-Term tests. The initial 30-day Long-Term test was carried out October 10 through November 9, 2005. A Long-Term operational demonstration commenced mid-November through mid-December 2005 and resumed the end of January through early March 2006. Long-Term tests of the redesigned grid delivery and injection system were conducted in 2007. The results from these different periods are presented below.

<u>Original Grid: 30-Day Continuous Injection</u>

The Long-Term test period was divided into two phases:

Phase I: Determine the minimum amount of sorbent needed to maintain effective mercury removal in accordance with project guidelines on the ESP field 7 (rear-box) injection grid (October 10 through 21) while monitoring particulate emissions.

Phase 2: Determine the minimum amount of sorbent needed to maintain effective mercury removal in accordance with project guidelines on the ESP field 5 (mid-box) injection grid (October 21 through November 9) while monitoring particulate emissions.

Independence typically burns a PRB coal. However, the plant burned coal from the ColoWyo Mine, which is significantly lower in mercury, on October 31 through November 2 and again on November 7 through the end of the Long-Term test period. Thus, the second phase of the Long-Term test includes data obtained while ColoWyo coal was burned.

In general, mercury removal during the Long-Term test period was not as high as was expected, based on previous results at other PRB power plants. The average mercury removal during this period was 69.6 ± 13.8%. In contrast to the trends observed during Baseline testing, mercury removal fluctuated with boiler load (Figure 26). During the length of the Long-Term test phases, these unexpected results were analyzed and potential reasons for them are detailed in the following sections. As was observed during the Parametric tests, sorbent injection does appear to impact mercury removal on the control side of the ESP box. This effect is most evident when the sorbent is injected in the rear-box location (Figure 25). This was also evident during post-injection visual inspections of the ESP B-box, which found PAC deposits spaced across the entire outlet wall of ESP B.

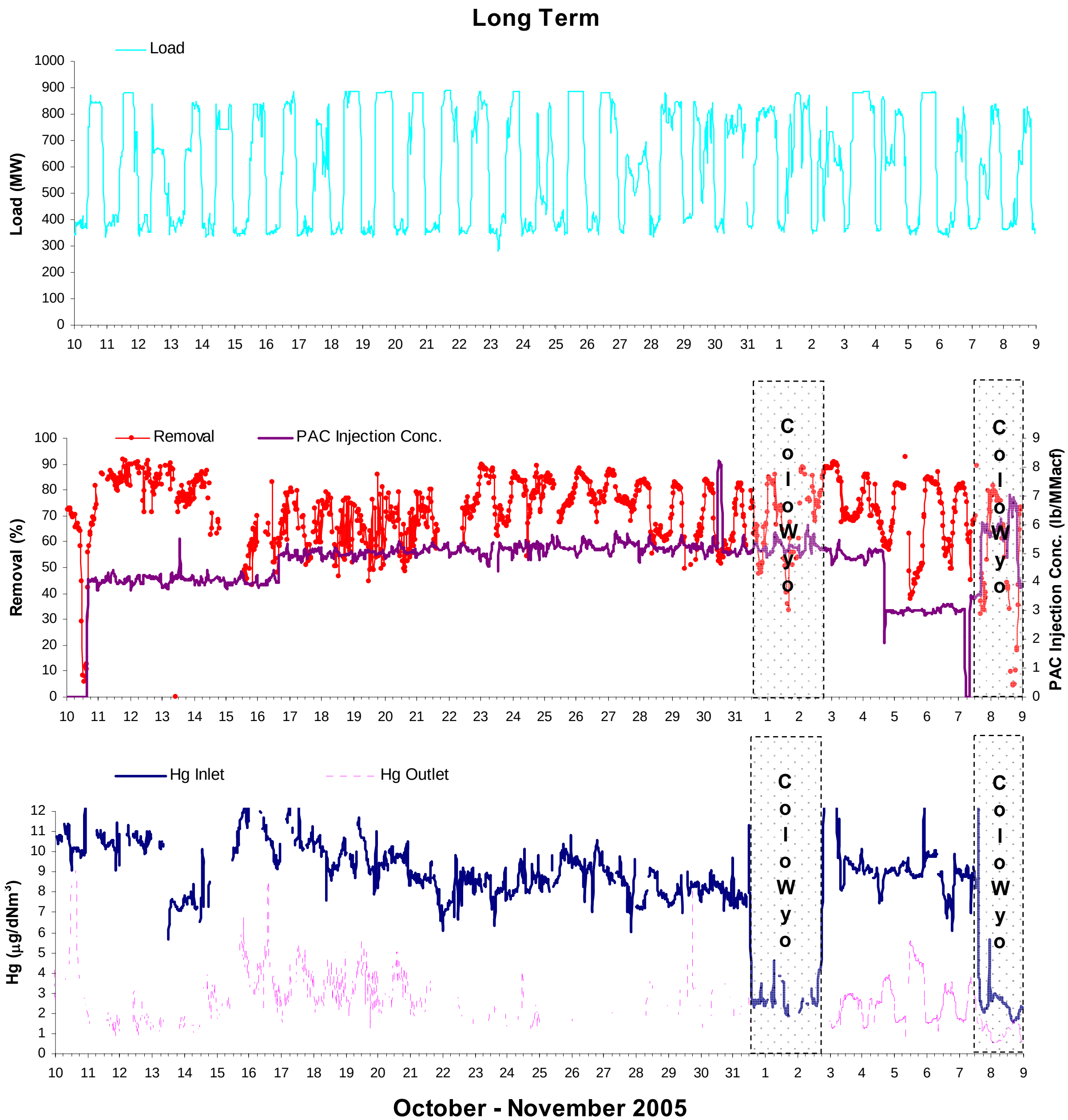


Figure 27. Mercury removal trends during Long-Term testing: October–November 2005. (Hg levels corrected to 3% O_2.)

In the middle of the first week of Long-Term testing, it became apparent that the S-CEM mercury analyzers were giving aberrant readings, particularly the outlet measurement, because the outlet mercury levels showed little variability. To verify the result of the S-CEM analyzers, a calibration was performed using a mercury calibrator through the probes. The results clearly indicated that the mercury removal results of the previous four days were questionable as the outlet filter was scrubbing a significant amount of mercury from the flue gas stream. Operating procedures were changed, and the frequency of calibrations increased, to prevent this situation from arising again. Subsequently, the PAC injection concentration was increased from 4 to 5 lb/MMacf to increase mercury removal efficiency to the target removal of 60–70% at full load.

Box-whisker plots of the total vapor-phase mercury removal efficiency (averaged over 30-minute intervals) of DARCO® Hg-LH during mid-box and rear-box injections at high (> 750 MW) and low (< 450 MW) boiler loads are given in Figure 28 and Figure 29. In Figure 28, the two left plots include the average OH Results for Total Hg removal efficiency for reference. In Figure 29, the upper half of the figure shows box-whisker plots of the average total vapor-phase mercury removal efficiency across the test and control sides of ESP B-box for various injection concentrations at the mid-ESP box injection location for boiler loads > 750 MW or < 450 MW while ColoWyo coal is burned. The lower half of the figure shows box-whisker plots of the total vapor-phase mercury levels at the test side inlet and outlet to ESP B-box for the same conditions. In the upper left plot, the average OH results for total Hg removal efficiency for this period is shown for reference. In the lower left plot, the average OH results for total Hg at the ESP inlet and outlet for this period are shown for reference. (OH values corrected to 3% O_2.)

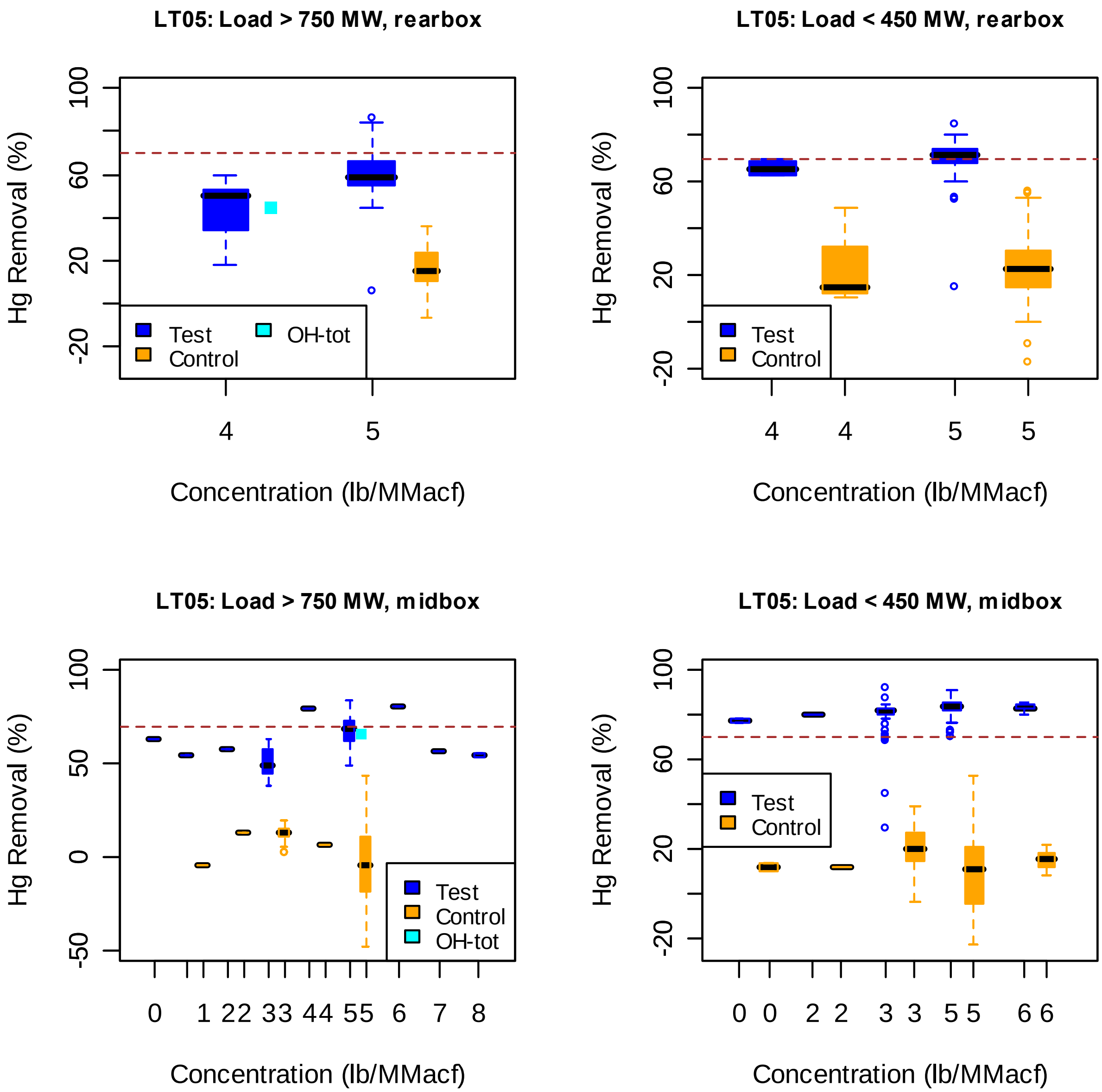


Figure 28. Average total vapor-phase mercury removal efficiency during DARCO® Hg-LH injection upstream of the final field.

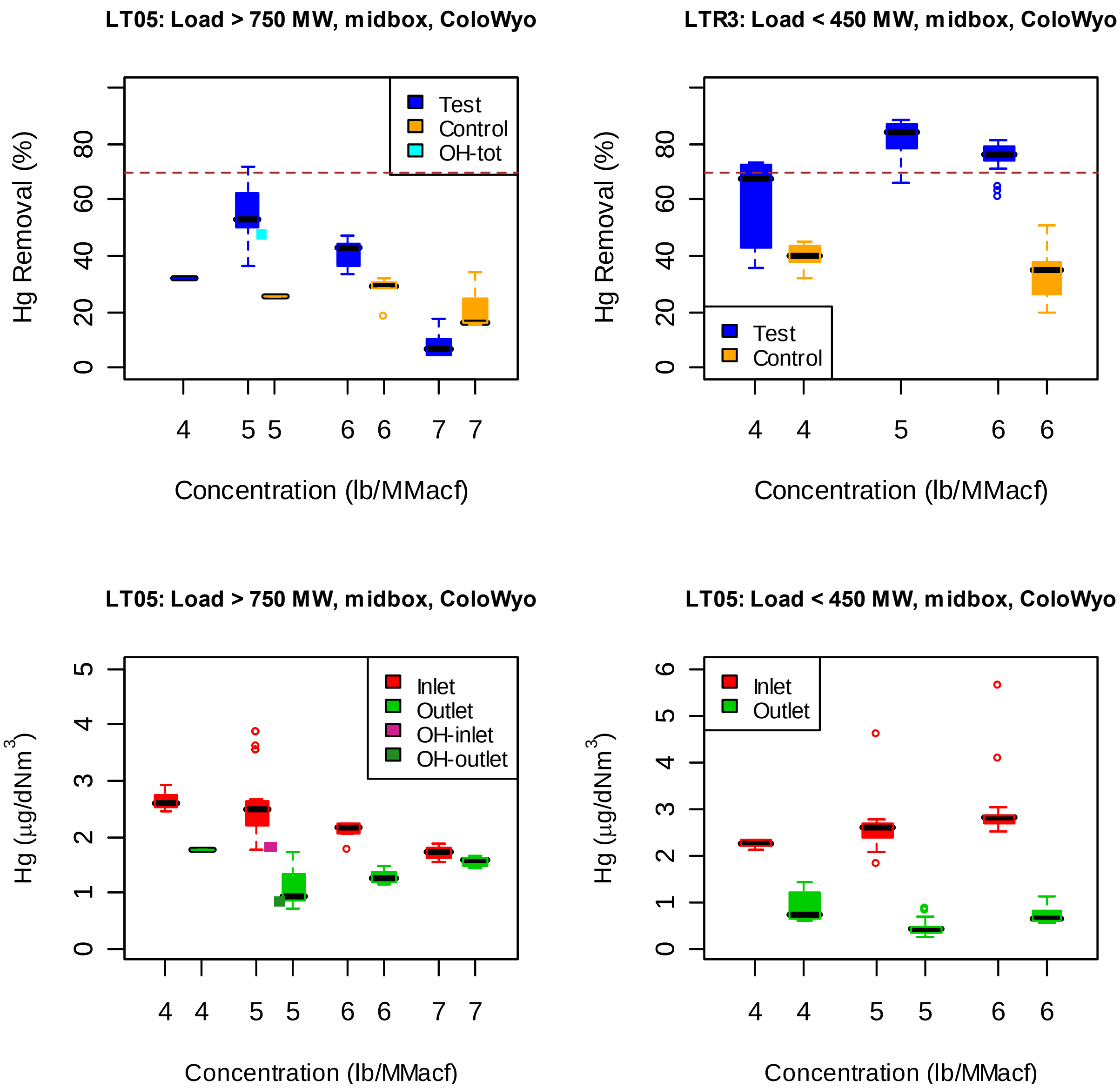


Figure 29. Average total vapor-phase mercury removal efficiency during DARCO® Hg-LH injection upstream of the middle collection field.

The relatively high mercury removal efficiencies observed during mid-box injection at low or no PAC concentrations are likely to be anomalies. These low injection concentrations were of short duration and the results likely to be influenced by the residual effects of preceding, higher injection concentrations that would include conditioning the duct work and ESP with PAC. The average efficiencies are given in Table 8.

Table 8. Average total vapor-phase mercury removal efficiency during 2005 Long-Term testing.

Boiler Load	Rear-Box Injection	Mid-Box Injection	Mid-Box Injection, ColoWyo
> 750 MW	59.7 ± 11.67%	65.4 ± 9.38%	45.4 ± 18.20%
< 450 MW	70.0 ± 8.22%	82.4 ± 5.95%	75.4 ± 10.89%

Sorbent performance under high load conditions when ColoWyo coal was burned was relatively poor. However, the average concentration of total vapor-phase mercury at the ESP inlet during Long-Term testing when PRB was burned was 9.07 ± 1.44 μg/dNm^3 in contrast to 2.54 ± 0.59 μg/dNm^3 when ColoWyo coal was burned (values corrected to 3% O_2). Moreover, it was not the intent of this test program to test the effectiveness of DARCO® Hg-LH with ColoWyo coal.

Three sets of triplicate Ontario Hydro runs were conducted during both Long-Term test phases and when ColoWyo coal was burned. A comparison of the OH results with average S-CEM readings and the average of duplicate STM run results from the corresponding times as the OH runs are presented in Table 9 (rear-box injection), Table 10 (mid-box injection), and Table 11 (mid-box injection, ColoWyo burned). As can be seen in the tables, except for the ESP inlet mercury levels for the first two runs of the first set of OH tests, the S-CEM and STM results tended to be higher than the OH results at the inlet to the ESP.

Not shown on the tables is the fraction of mercury reported as particulate mercury on the outlet Ontario Hydro filters. Recall that there can be a bias using the Ontario Hydro Method because the sample gas flows through a cake of ash that forms on the sampling filter. If the particulate has an affinity for mercury, this filter cake may scrub mercury from the sample gas stream. For the tests shown in Tables 9 through 11, the fraction of mercury reporting as particulate mercury on the outlet sampling filters ranged from 62 to 85% (Table 9 data), 44 to 78% (Table 10 data), and 16 to 29% (Table 11 data). At the inlet where much more ash was present, but no activated carbon, the fraction of mercury reporting as particulate mercury was typically less than 2%. These data suggest some activated carbon with remaining capacity for mercury was exiting the ESP to bias the Ontario Hydro speciation results. A bias is suspected because the total mercury measured with the Ontario Hydro Method matches the S-CEM vapor-phase measurements fairly well. The full Ontario Hydro reports are included in Appendix D.

Table 9. Mercury levels across ESP B-box obtained by different methods during injection of 5 lb/MMacf DARCO® Hg-LH in the rear-box location. (OH is Hg^{2+} + Hg^0; S-CEM is total vapor-phase mercury; all values given in μg/dNm^3 and corrected to 3% O_2.)

Oct. 18–19, 2005	OH (In)	OH (Out)	S-CEM (In)	S-CEM (Out)
Run 1	12.39	6.24	9.0 ± 0.31	3.65 ± 0.64
Run 2	10.45	3.97	9.42 ± 0.22	3.80 ± 0.81
Run 3	8.52	6.63	10.45 ± 0.26	4.35 ± 1.08

Table 10. Hg levels across ESP B-box obtained by different methods during injection of 5 lb/MMacf DARCO® Hg-LH in the mid-box location. (OH is Hg^{2+} + Hg^0; S-CEM and STM are total vapor-phase mercury; all values given in µg/dNm^3 and corrected to 3% O_2.)

Oct. 25–26, 2005	OH (In)	OH (Out)	S-CEM (In)	S-CEM (Out)	STM (In)	STM (Out)
Run 1	7.99	2.31	8.96 ± 0.45	2.50 ± 0.9	NA	2.67 ± 0.97
Run 2	7.21	2.22	9.90 ± 0.28	2.50 ± 0.11	NA	2.55 ± 0.41
Run 3	7.08	2.99	9.21 ± 0.24	2.12 ± 0.11	12.79 ± 7.00	NA

Table 11. Hg levels across ESP B-box obtained by different methods during injection of 5 lb/MMacf DARCO® Hg-LH in the mid-box location. ColoWyo coal burned. (OH is Hg^{2+} + Hg^0; S-CEM and STM are total vapor-phase mercury; all values given in µg/dNm^3 and corrected to 3% O_2.) NB: Run 2 was aborted.

Nov. 1–2, 2005	OH (In)	OH (Out)	S-CEM (In)	S-CEM (Out)	STM (In)	STM (Out)
Run 1	1.39	1.11	2.38 ± 0.62	1.45 ± 0.19	2.7 ± 2.01	NA
Run 3	2.24	0.56	3.13 ± 0.83	0.74 ± 0.11	NA	1.45 ± 0.49

Run 2 of the third triplicate run of Ontario Hydro data was shut down as a result of the plant having to respond to a load change request. As a result, the data from the run were compromised and were not analyzed.

Long-Term Speciation Results

Given the speciation results obtained during Parametric testing and the desire to monitor the total vapor-phase outlet mercury levels on the control side, limited speciation measurements were made with the S-CEM at the ESP B test outlet during the Long-Term test period. Speciation measurements were made with the S-CEM during the second phase of Long-Term testing (mid-box injection) in conjunction with Ontario Hydro testing. The averaged percent elemental mercury (Hg^0/(Hg^{2+} + Hg^0)) as determined by the Ontario Hydro tests conducted during the first phase of Long-Term tests (October 17–18, 2005; rear-box injection of 5 lb/MMacf DARCO® Hg-LH) was 73.3 ± 8.37% at the inlet and 55.6 ± 21.1% the outlet. During these tests, particle bound mercury comprised 57% of the total mercury measured at the ESP outlet. Thus, it is worthwhile to note the averaged amount of elemental mercury relative to the total mercury (i.e., elemental + oxidized + particulate) across the ESP as determined by the same round OH tests: 76.5 ± 8.57% at the inlet and 21.9 ± 9.37%.

Results under the conditions when 5 lb/MMacf of DARCO® Hg-LH was injected in the mid-ESP box location at high (> 750 MW) and low (< 450 MW) boiler loads and while PRB or ColoWyo coal was burned are presented in Figure 30. The OH tests conducted in late October, like those a week earlier, also indicated that particle bound mercury comprised a significant portion of the total mercury at the ESP outlet. Thus, the elemental mercury relative to elemental and oxidized mercury and relative to total mercury (elemental + oxidized + particulate) mercury as determined by the OH tests when PRB was burned are both shown in the figure. As was observed during the Parametric tests, there is a substantial drop across the ESP in the percentage of elemental mercury present.

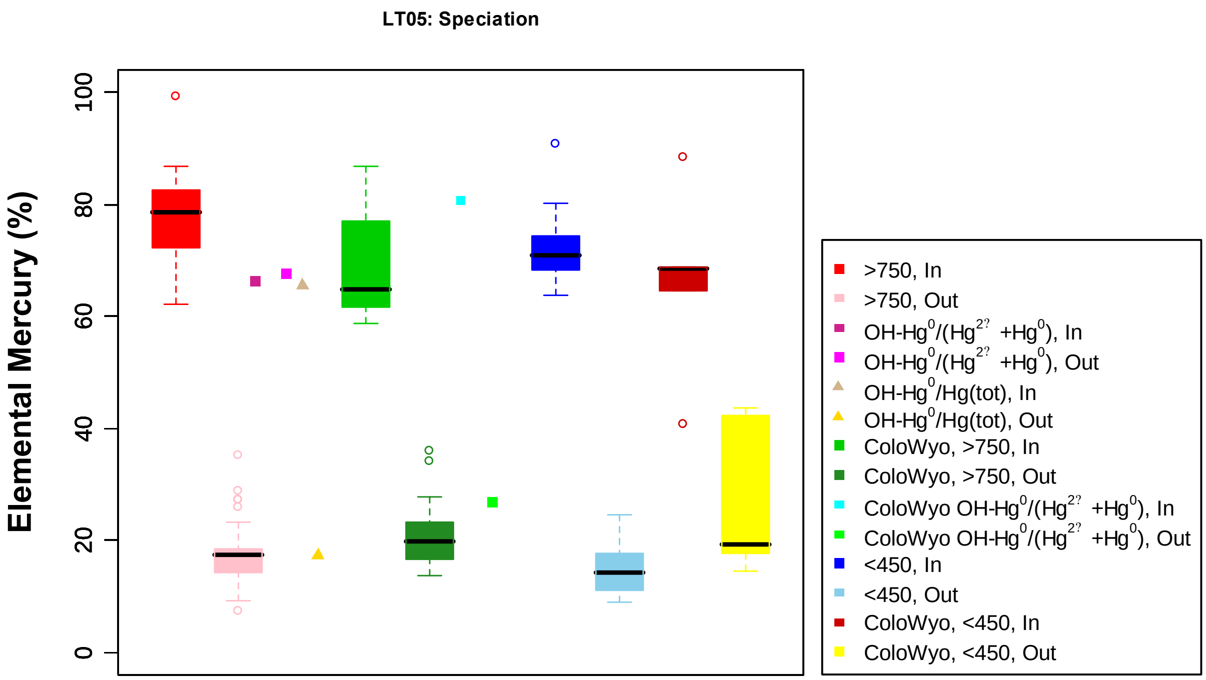


Figure 30. Comparison of mercury speciation across the ESP B-box at the mid-box injection location with 5 lb/MMacf of sorbent under high (> 750 MW) and low (< 450 MW) boiler load conditions that overlapped times when Ontario Hydro tests were conducted during Long-Term testing 2005.

Long-Term and Parametric Comparison

A comparison of the average performance of DARCO® Hg and DARCO® Hg-LH at various injection concentrations during the 2005 Parametric and Long-Term test sequences is shown in Figure 31. The higher removal rates during the Long-Term testing occurred during lower unit load, and the lower removal rates occurred during higher unit load. The points generally show that removal rate increases with injection concentration. This trend agrees with the general trends from other testing programs on PRB plants without SO_3 flue gas conditioning, although for the TOXECON II™ process, the required injection concentration for a given removal rate is higher.

Another statistical anomaly is the difference in removal rates at the same injection concentrations between Parametric testing and Long-Term testing. During the several Parametric test sequences, removal rates approached that expected for a brominated PAC being injected upstream of an ESP on a plant firing PRB coal. The mercury removal measured during Long-Term testing was much lower. It is believed that the difference in performance is mainly a result of pluggage in the TOXECON II™ injection grid. There is extensive discussion concerning injection system design later in the report.

The performance of DARCO® Hg compared to DARCO® Hg-LH during Parametric testing is also interesting. Typically, injection of a bromine-treated PAC results in significantly better performance in a halogen-deficient gas stream, such as PRB-derived flue gas. At Independence, the mercury removal with DARCO® Hg were not significantly worse than the mercury removal achieved with DARCO® Hg-LH. It is likely that limitations resulting from poor sorbent distribution affected the performance. It is also possible that DARCO® Hg benefited from the high baseline mercury oxidation across the ESP, often as high as 60%. The traditional injection location is upstream of the ESP, where no corona-induced oxidized mercury is present. Thus, the TOXECON II™ configuration and the specific electrical characteristics of Independence may have contributed to the performance of DARCO® Hg.

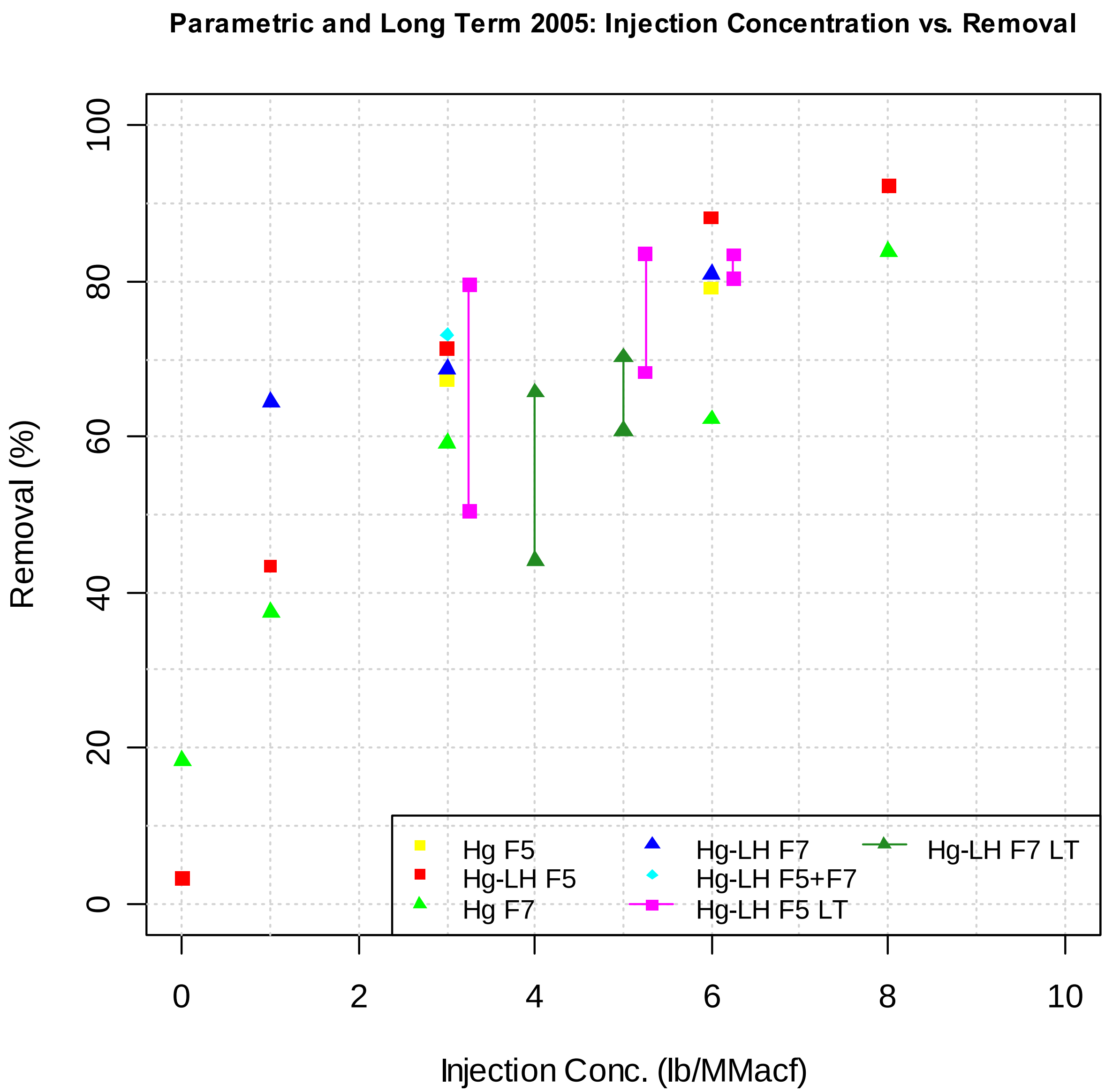


Figure 31. Comparison of DARCO® Hg and Hg-LH performance from Parametric and Long-Term (LT) tests at the mid-ESP (F5) and rear-ESP (F7) injection locations.

Long-Term Operational Demonstration

After completion of the ash recycling tests in mid-November, a Long-Term operational demonstration injecting DARCO® Hg-LH was conducted from November 16 through 21, November 29 through December 20, 2005, and January 23 through March 10, 2006. Prior to commencing the demonstration, both the mid-and rear-ESP box injection grids were inspected. The ash recycle mixture had been injected into the grid in front of ESP field B-5 and this grid was severely plugged. The grid in front of ESP field B-7 was relatively clear. The injection grids were cleaned and the bottom portion of the grid in front of ESP field B-5 was replaced. During the demonstration period, mercury removal rates essentially duplicated the results attained during Long-Term testing under similar conditions such as injection concentration, coal type, injection location, and boiler load. During several days of the demonstration (November 29 through December 2, 2005), the ID fan for the ESP A-C pair of boxes was down and Unit 2 ran at reduced load. Overlapping with this period, the ESP B field 7 was at low or no power (November 30 through December 12, 2005).

The first week of the demonstration period provided on opportunity to investigate one possible explanation for the difference in sorbent performance at high and low boiler loads, a phenomenon not observed at other test sites. Because flue gas temperatures increase with boiler load, flue gas flows also increase. Consequently, residence time within the ESP decreases with increasing load. At high loads, the residence time prior to the entry of the flue gas–PAC mixture was approximately one second. At lower loads, the residence time could increase approximately four-fold. The question was whether the residence time within the spacing between the T/R fields long enough at high load conditions to allow for the complex vapor-phase mercury–halogenated activated carbon interaction. Injecting sorbent in the mid-box location (field B-5) while the middle field (T/R set B-5) is off effectively increases residence time. T/R set B-5 was turned off from the morning of November 17 through the morning of November 19, 2005, and the total vapor-phase mercury across the ESP was measured. A comparison of the mercury removal efficiency when the T/R set B-5 was on and off is given in Figure 32. As shown in the figure, turning off T/R set B-5 did not produce an improvement in performance at either high (> 750 MW) or low (< 450 MW) boiler loads.

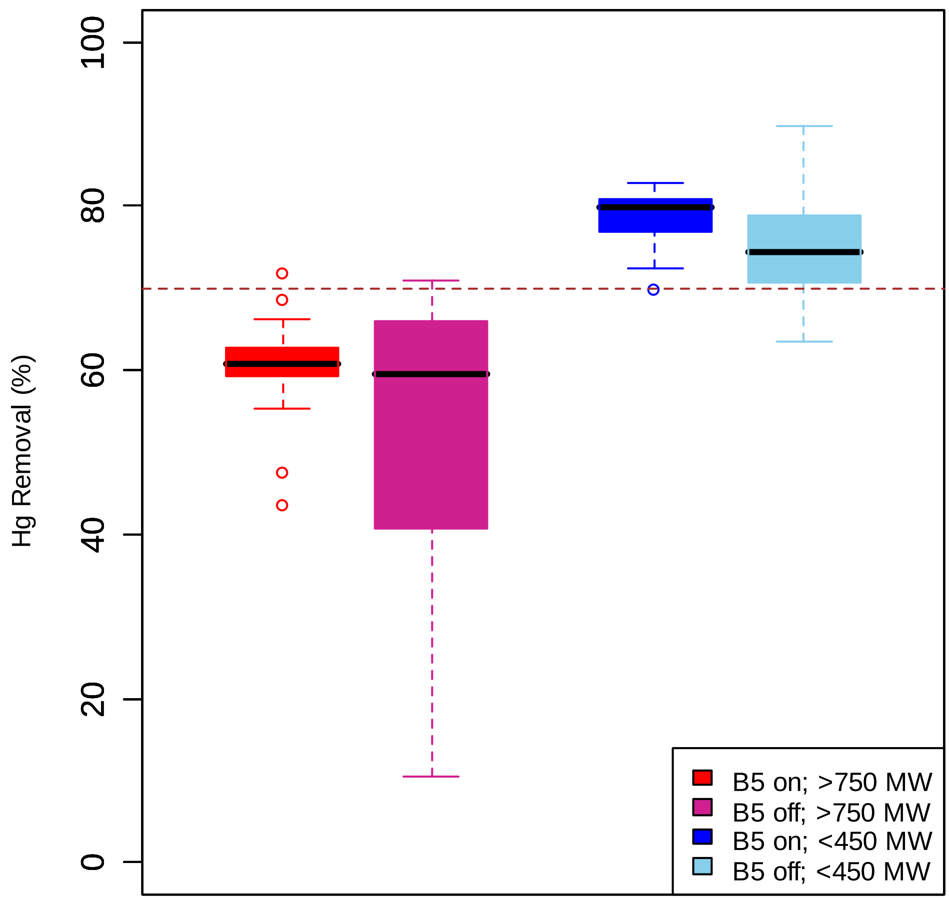


Figure 32. Box-whisker plots of the 30-minute averages of mercury removal efficiency at high (> 750 MW) and low (< 450 MW) boiler loads when 4–5.5 lb/MMacf of DARCO® Hg-LH was injected mid-box and the middle field (B5) was on or off.

If mercury concentrations are stratified within the ESP, this stratification may be limiting the efficacy of the TOXECON II™ system. On December 13, 2005, an STM carbon trap traverse of the ESP B test side outlet duct was carried out using a two-point depth sample of three ports. The results are shown in Figure 33 along with the corresponding average mercury concentration at the ESP inlet and outlet as given by the S-CEMs during the STM sampling period. All tests were conducted during high (> 750 MW) boiler load. As can be seen in the figure, the mercury concentration varies considerably depending upon the depth of the sampling probe. The mercury concentration at a depth of 50 inches is near the inlet concentration, suggesting that very little PAC was present at this depth. This is a strong indication that PAC distribution was poor. These measurements were collected following the ash/PAC recycle tests when lance pluggage was experienced, as discussed in the ash/PAC recycle section of the report included below. The data also suggest stratification from side-to-side across the ESP. The STM measurements were collected at two depths within a particular port simultaneously, but approximately 1.5 hours separated measurements in the different ports. The SCEM reported a significant change in the mercury concentration at the ESP outlet during the time elapsed between STM measurements. If the STM measurements were normalized to the SCEM measurements, a significant variation in the relative mercury would be apparent.

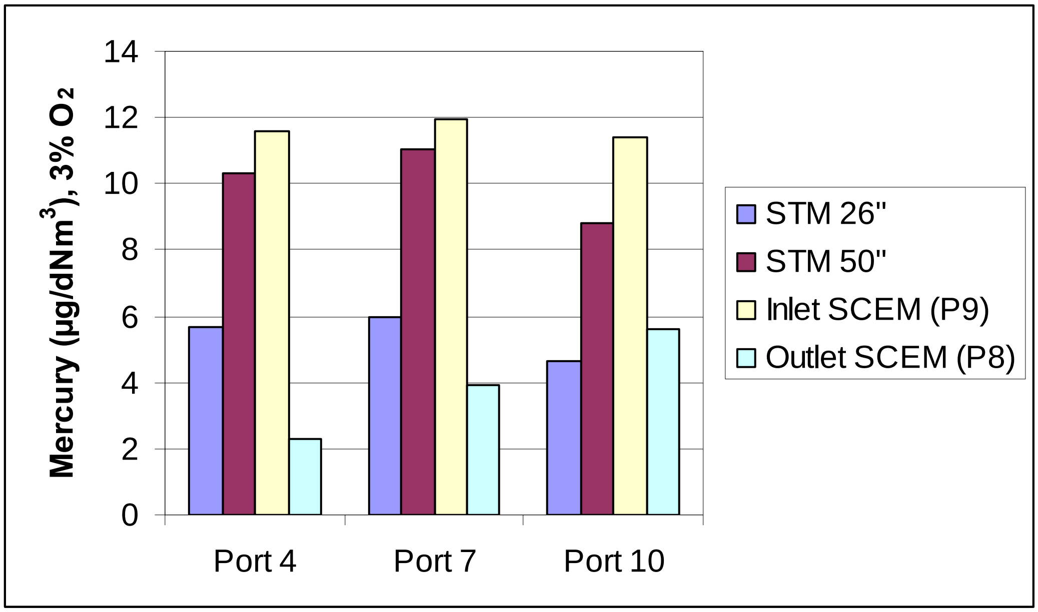


Figure 33. Total vapor-phase mercury at various locations in the test side of ESP B-box when 5.5 lb/MMacf of DARCO® Hg-LH was injected mid-box during high (> 750 MW) boiler load on December 13, 2005. Data for outlet ports 4, 7, and 10 are STM results. Concurrent S-CEM readings at the inlet and outlet are shown for reference with the corresponding port location denoted as either P9 (inlet port 9) or P8 (outlet port 8). Values corrected to 3% O_2.

A possible explanation for sorbent performance to fluctuate with changes in the boiler load is that changes in flue gas flow rates influence sorbent distribution patterns within the ESP. Injecting sorbent upstream of the ESP allows the sorbent to be dispersed more uniformly within the flue gas stream that passes through the ESP. Near the end of the demonstration period (March 5 through 7, 2006), DARCO® Hg-LH was injected at various concentrations into the test inlet to ESP B-box and the results are shown in Figure 34. During this segment of the test sequence, the boiler load remained above 640 MW. As can be seen in the figure, sorbent performance exceeded the target removal efficiency of 70% for all injection concentrations. The average mercury removal efficiency during this test segment was 81.18 ± 6.70%. Moreover, the pre-ESP injection at a relatively low concentration of 1 lb/MMacf exceeded previous tests results when sorbent was injected in either the mid- or rear-box locations. Although the pre-ESP test does not prove that the sorbent distribution within the ESP varies with load, it lends support to this possibility. Additional evidence for poor sorbent distribution is provided by the modeling results discussed later in this report.

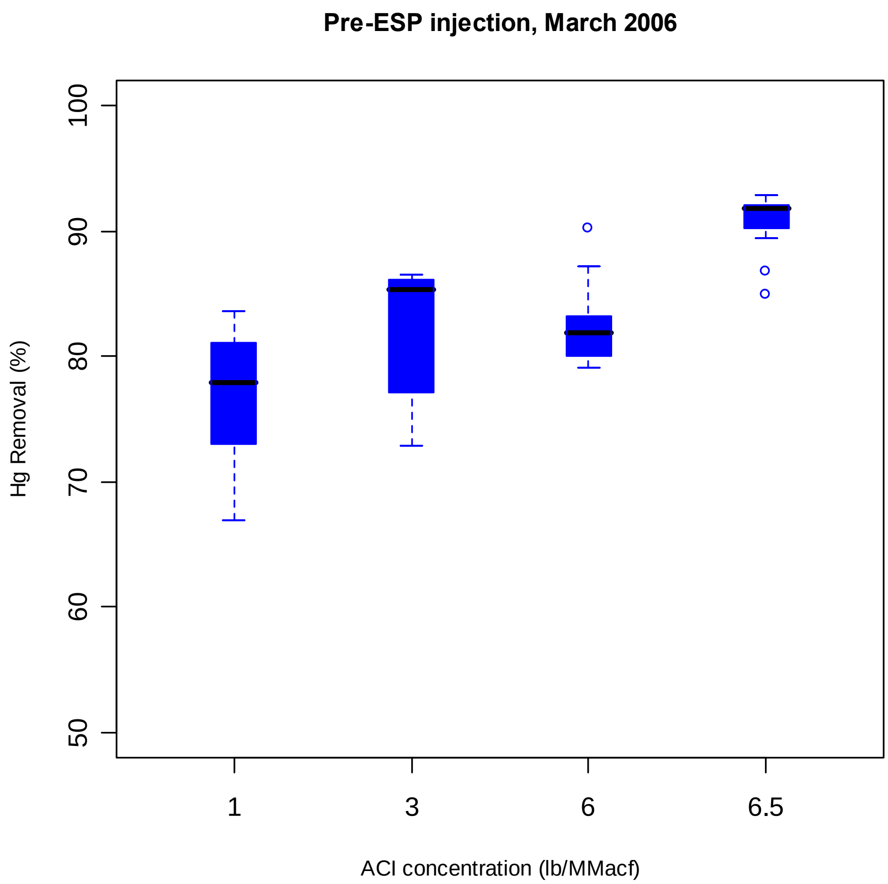


Figure 34. Box-whisker plots of mercury removal efficiency across the ESP when DARCO® Hg-LH was injected at the inlet of the ESP at various injection concentrations.

Extended Test with Redesigned Grid

Based upon the positive results achieved during 2007 Parametric testing, the decision was made to continue testing for a 30-day trial to evaluate long-term removal trends and operational constraints on the new lance design.

During the initial few days of testing, operational problems associated with the silo feed controls were encountered that prevented injection at PAC concentrations below 3 lb/MMacf. In addition, difficulties maintaining appropriate air flow through lances were encountered that were a result of PAC depositing in lances and/or distribution system. These problems continued to create operational difficulties throughout the 30-day test.

A summary of the mercury removal achieved during the 30-day test is shown in Figure 35. Data from previous test periods are included for reference. As shown, the mercury removal with the TOXECON II™ arrangement and the modified lances was similar to the removal achieved with injection upstream of the ESP. Little mercury removal performance difference was noted across a wide range of PAC injection system operating parameters. It is unclear whether the characterization of differences in mercury removal from changing the operational parameters was clouded by the operational difficulties encountered.

A trend graph showing inlet and outlet vapor-phase mercury, mercury removal, and injection concentration is presented in Figure 36. The injection concentration is shown per injection train. There are two injection trains on the feed system installed at Independence. Operating the west train was more problematic than operating the east train. For a period, the west train was isolated and the system was only feeding carbon the east train. This resulted in higher mercury measurements at the outlet of the ESP, likely due to the location of the S-CEM and difficulties measuring representative flue gas when only 1/32 of the unit was being treated.

Some S-CEM data were lost during the test following a computer malfunction. Since only one S-CEM was in use to measure both the inlet and outlet locations, no data are shown on the trend graph for either location following the data loss.

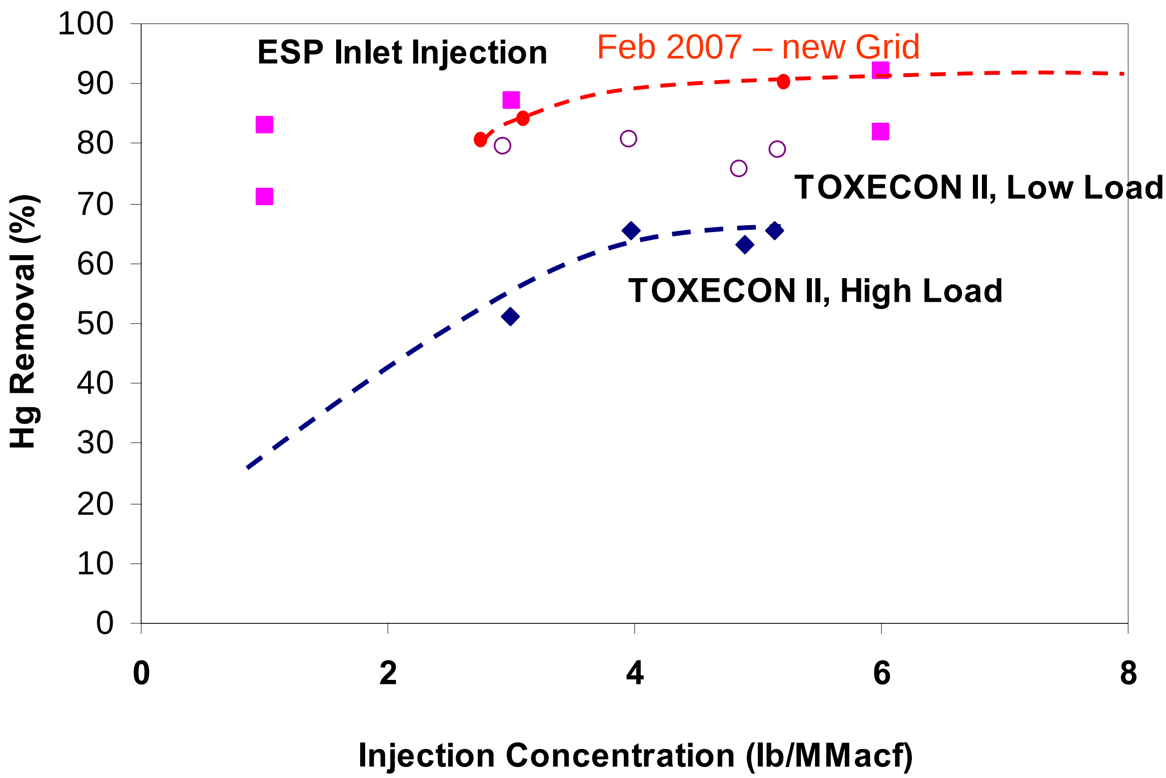


Figure 35. Mercury removal comparison of injection location and grid design.

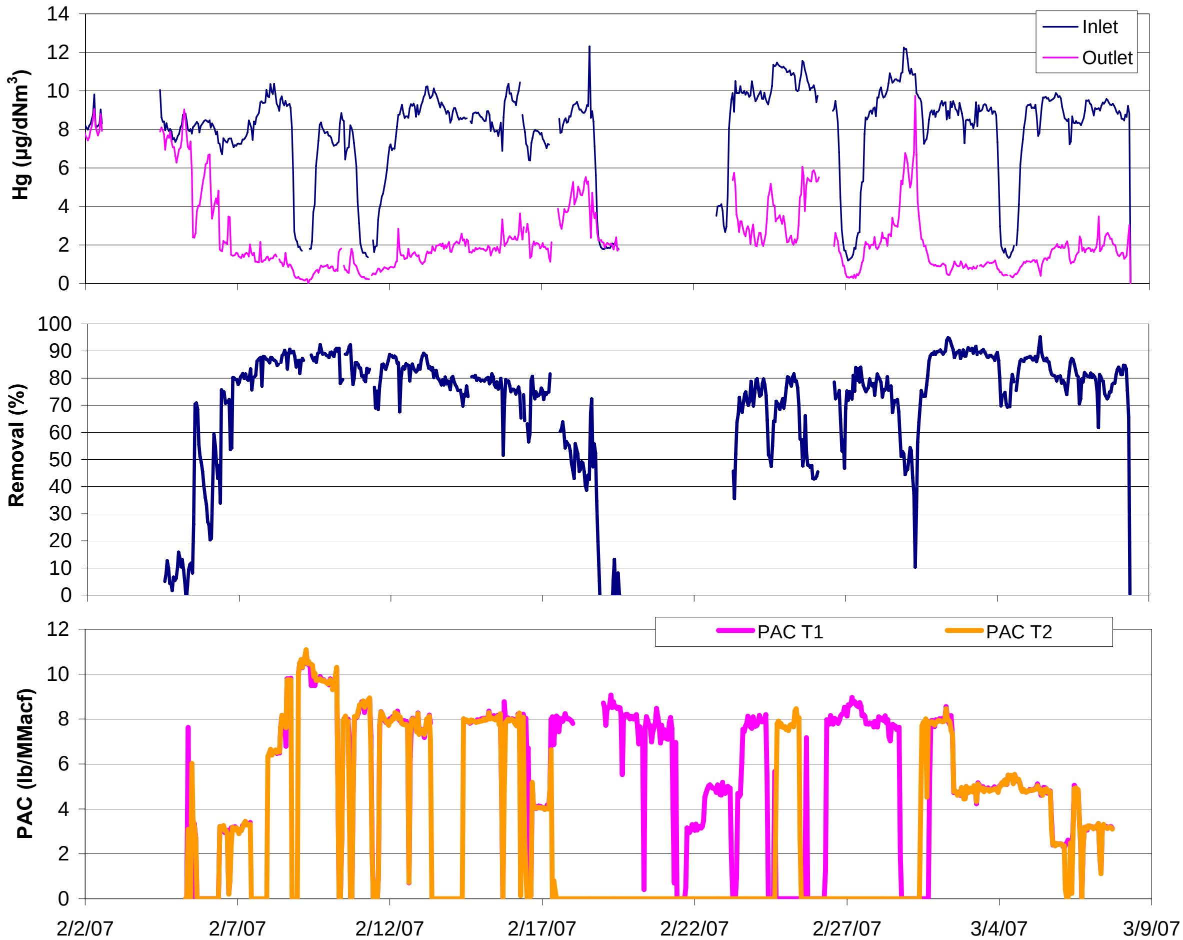


Figure 36. Mercury removal comparison of injection location and grid design.

Ash/Carbon Recycle Test Results

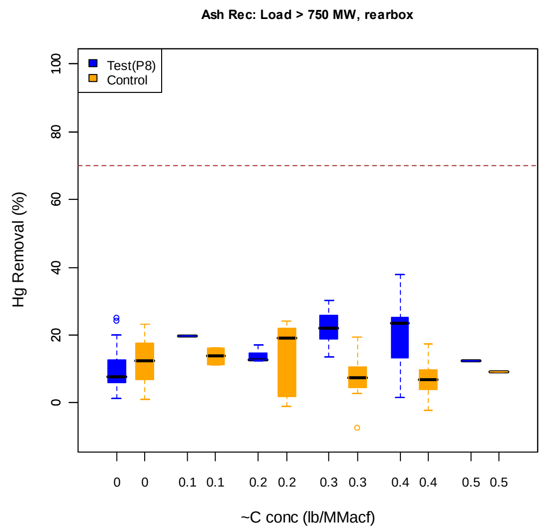
During most of the ash recycle test (November 9–13, 2005), the recycle mixture was injected in the mid-ESP location. The recycle mixture was initially estimated to contain approximately 20 to 30% carbon, based on the average % LOI results of ash samples that were taken from the rear hoppers during Parametric and Long-Term testing. Based on later ash analysis from the actual injection material, the PAC percentage could have been as low as 12%.

Some challenges operating the injection system were encountered during the recycle test. Differences in material handling characteristics and density of the mixture compared to either ash or carbon alone were noted during the ash/carbon recycle test at Independence. Although the bulk density of the test PACs is approximately half that of the fly ash at Independence, the silo delivery system was able to feed the ash/carbon mixture into the injection system. However, calibrating the auger feed rate proved challenging because the density of the ash/carbon mixture varied from 2 to 2 1/2 times that of PAC alone. Prior to recycling testing at Independence, the ash/carbon mixture had been stored in the test silo over an extended period, longer than the normal storage times for fly ash that was sold. Owing to the relatively high humidity of the area and the use of plant air to fluidize while transporting, a significant percentage of moisture may have penetrated the recycle material. The presence of moisture in the recycle material could account for both the increase and the variation in density observed.

Another challenge during the recycle test was monitoring the fraction of carbon in the mixture. The carbon content of ash/PAC mixture samples from the recycle tests was 12 to 13% based upon LOI analyses of this material. This required a higher injection rate to achieve the desired carbon injection concentration. The expected carbon content was nominally 33%, based upon the carbon in DARCO® Hg-LH (derived from lignite coal and contains nominally 25% ash) and the baseline ash (LOI analyses of the baseline fly ash from Independence indicates nominally 0.25% LOI carbon). LOI analyses of ash collected downstream of the injection grid during Long-Term testing ranged from 25 to 55% LOI. The ash/PAC recycle material was collected in the segregated ash storage silo at Independence. This system was also used to segregate all the ash from burning ColoWyo coal. The ColoWyo coal ash had to be segregated at the request of the Arkansas DEQ since it had not been analyzed for use in the post-combustion ash utilization streams. The plant performed two 3-day test burns of the ColoWyo coal in the preceding two weeks prior to the ash recycle test. Additional dilution occurred when the segregated silo was brought on-line prior to emptying the downstream ash hoppers and did not switch back to the main ash silo until after the upstream hoppers began to empty and all PAC-laden ash was cleared from the conveying system. This procedure prevented the PAC from entering the normal ash collection silo but resulted in additional ash in the segregated ash silo.

As mentioned above, the recycle test sequence was curtailed when it was evident that the recycle material was not entering the ESP test fields. A subsequent inspection of the injection grid revealed that the ash/carbon mixture had plugged the injection lances, particularly in the lower section of the injection grid. While the injection grid had experienced some pluggage during the Long-Term test using standard PAC materials for injection, the change in the composition of the injection material lead to increased significant pluggage issues. STM measurements conducted in December indicated lance pluggage in the lower sections. A subsequent internal inspection of the ESP provided an opportunity to remove the lower sections of the injection lances for inspection. The color change from DARCO® Hg-LH to ash-Hg-LH mixtures was clearly evident in the removed sections of injection lances. The lower sections of the lances had pluggage from standard PAC, and then above that, there was substantially increased pluggage from just several days of ash recycle testing. This increased pluggage could well have occurred due to the potential higher moisture content of the recycled ash mixture.

Figure 37 shows the mercury removal efficiency attained during the ash recycle tests at various carbon concentrations at high (> 750 MW) and low (< 450 MW) boiler loads. Consistent with the results from the Long-Term tests, the recycle mixture performance improved at low boiler loads. Overall, mercury removal during the ash/carbon recycle testing was considerably less than that observed when using DARCO™ Hg-LH alone. However, the concentration of carbon injected during the ash recycle sequence was much less than that during either the Parametric or Long-Term tests.



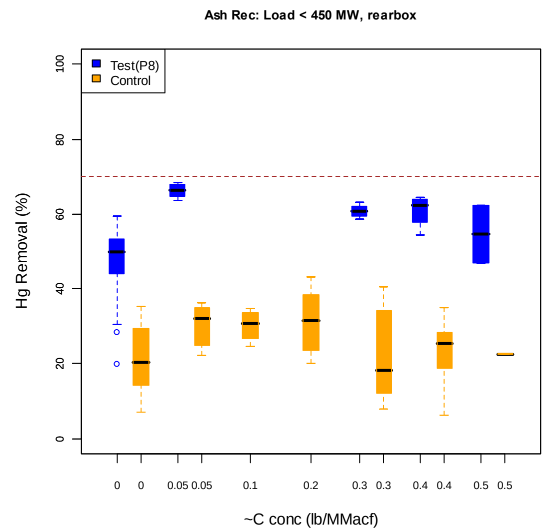


Figure 37. Box-whisker plots of the mercury removal efficiency across the ESP during the Ash Recycling tests.

At the completion of the ash recycle testing (November 14, 2005), the mixture remaining in the silo was injected into inlet test duct of the ESP B-box at high rates (~600 lb/hr). During this portion of the test, two sample probes from an S-CEM were placed at the ESP B test outlet duct at depths of 26 inches (port 9) and 50 inches (probe 8). Figure 38 shows trend plots the mercury concentration at the sample points along with the carbon concentration and boiler load. As can be seen in the figure, the mercury levels are quite low, indicating that injecting large amounts of the ash mixture (carbon concentrations of approximately 4 lb/MMacf) is effective at removing a significant amount of mercury. The results also indicate little stratification was present as the total vapor-phase mercury measurements at the two sample depths were very close and trended together.

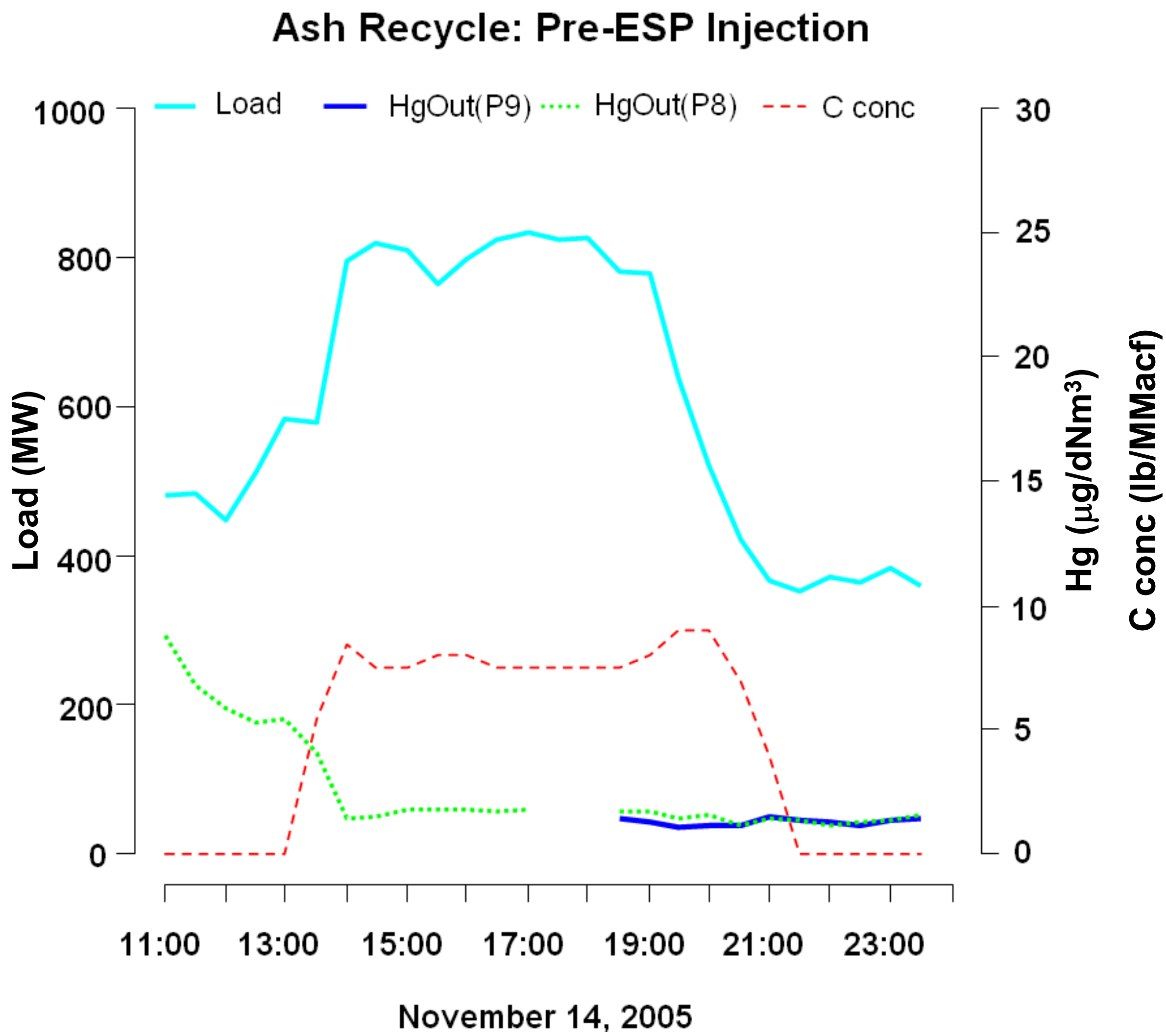


Figure 38. Plot of total vapor-phase mercury at ESP B 23 inches into outlet duct at port 9 and 50 inches into outlet duct at port 8. Also included is the boiler load and approximate concentration of carbon injected into the inlet duct of the ESP during the ash recycle test (November 14, 2005).

Modeling Results

During the testing sequence, it became evident that the injection grid and delivery system suffered design flaws that resulted in poor sorbent distribution and potential pluggage and subsequent lower than expected levels of mercury removal. Three modeling efforts were undertaken to better characterize the limitations of the original system and to redesign a more effective system. One approach (carried out by REI) employed computational fluid dynamics (CFD) to model (a) the PAC and transport air distribution in four lances (Appendix E1) and (b) the PAC, transport air, and flue gas distribution traveling through ESP (Appendices E2–3). A second approach (carried about at NELS) involved testing (a) a full-scale section of the injection grid in a wind tunnel and (b) a 1/12 scale model of one-half of one ESP box (Appendix E4). The third approach (carried out by ADA-ES) involved a physical testing of (a) a single nozzle to determine powder spray patterns, (b) the effects of various nozzle configurations, and (c) a full-size lance to measure sorbent mass loading. In general, results from the physical modeling indicate a defined jet and plume from a round hole, CFD modeling show transport air and PAC channeling between ESP plates, and CFD modeling show some vertical dispersion of plume within ESP plate space. Further details of these efforts are included below.

CFD Modeling of Grid and ESP

Results from the REI's CFD models indicate that transport air from lances is uniform among holes. However, PAC distribution varies with particle size. REI places relatively high confidence in the CFD technique for accurately modeling the transport air and lower confidence in the technique for accurately modeling PAC distribution. In particular, the latter models indicate possible trends, not absolute distribution. The CFD results for PAC distribution relative to the grid are summarized in Figure 39.

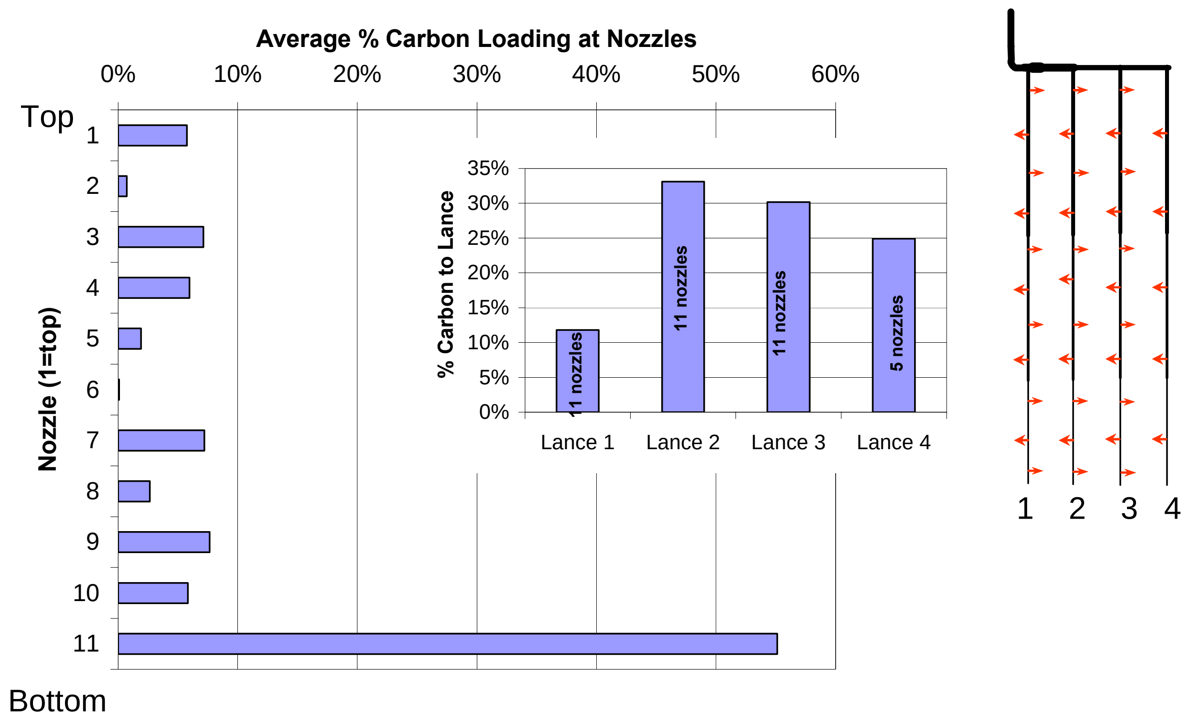
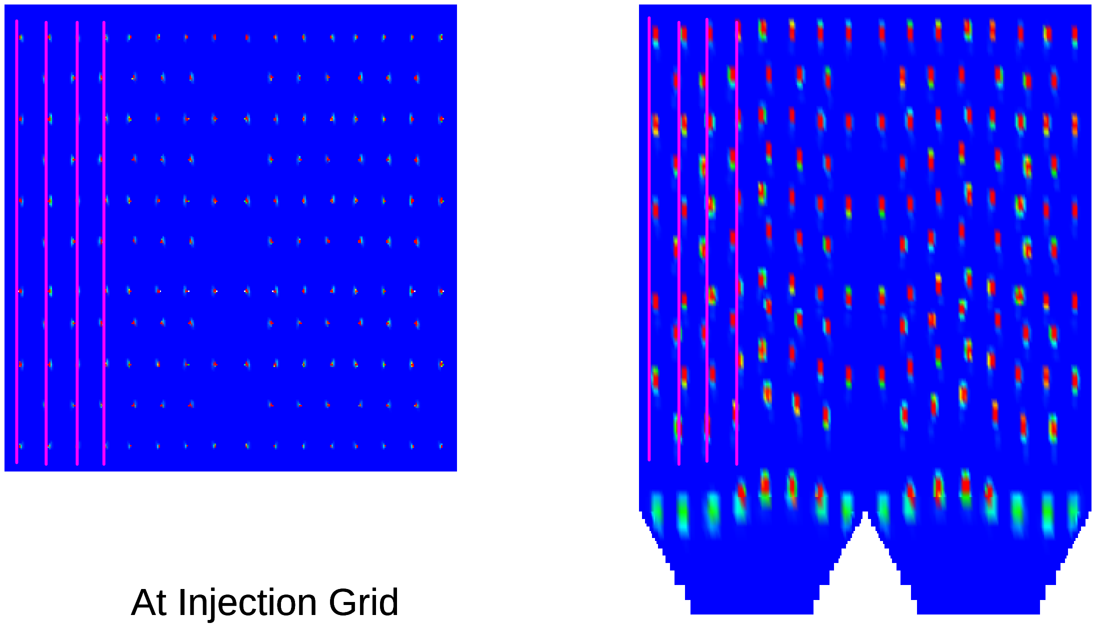


Figure 39. CFD model of average carbon distribution from nozzles along the length of an injection lance as well as from one-half of the injection grid system.

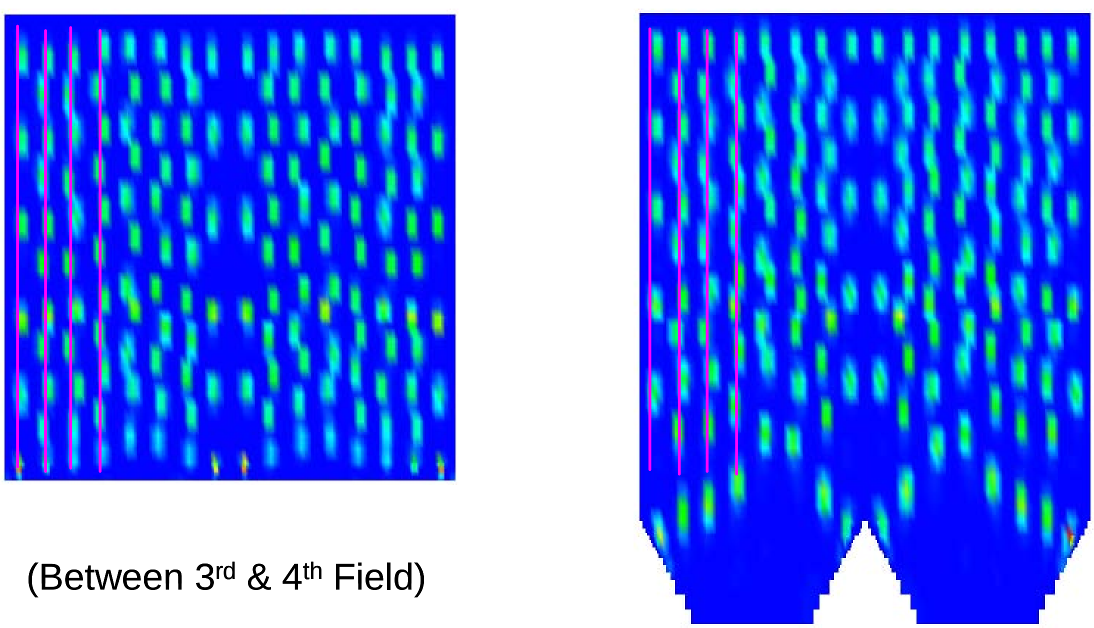
When modeling the ESP, REI mirrored the half grid model from grid modeling efforts. The CFD ESP model does not consider PAC collection on plates. Overall, the results show PAC is channeling between ESP plates, is bound by the plates, and diffuses up and down but not side to side. Snapshots of the CFD model results of carbon particle distribution in the middle and rear of the ESP box are given in Figure 40 and Figure 41, respectively.



At Injection Grid
(Between 2nd & 3rd Fields)

Mid 3rd Field

Figure 40. CFD model results of carbon particle distribution in the middle of the ESP.



(Between 3rd & 4th Field)

Mid 4th Field

Figure 41. CFD model results of carbon particle distribution in the rear of the ESP.

The conclusions from the REI report are that:

1. Sorbent carrier air does not mix well with flue gas—there are low carrier air concentration gaps due to the existence of collection plates.

2. Particle distribution has negligible effect on carrier air distribution inside the ESP.

3. Activated carbon particles are not well dispersed in the third and fourth collection fields
   a. Very limited particle penetration along ESP width.
   b. Some gaps between collection plates have almost no particles entering.

4. Higher particle bulk densities are predicted near the hopper
   a. The hole at the bottom of the lance has higher particle flow rate, especially for large particles
   b. Flue gas tends to circulate through the hoppers, re-entraining the carbon particles.

Physical Modeling of ESP B-box

The physical modeling that NELS carried out in a wind tunnel using existing holes in the original lance design and smoke rather than PAC indicated that (1) penetration varies with nozzle exit velocity and (2) the jet starts out cohesive, then plumes (Figure 42). Research showed that there were no commercial dilute phase nozzles for powder distribution. Of the commercial liquid nozzles tested, the nozzles exhibited various spray patterns, usually pluming right at the nozzle.

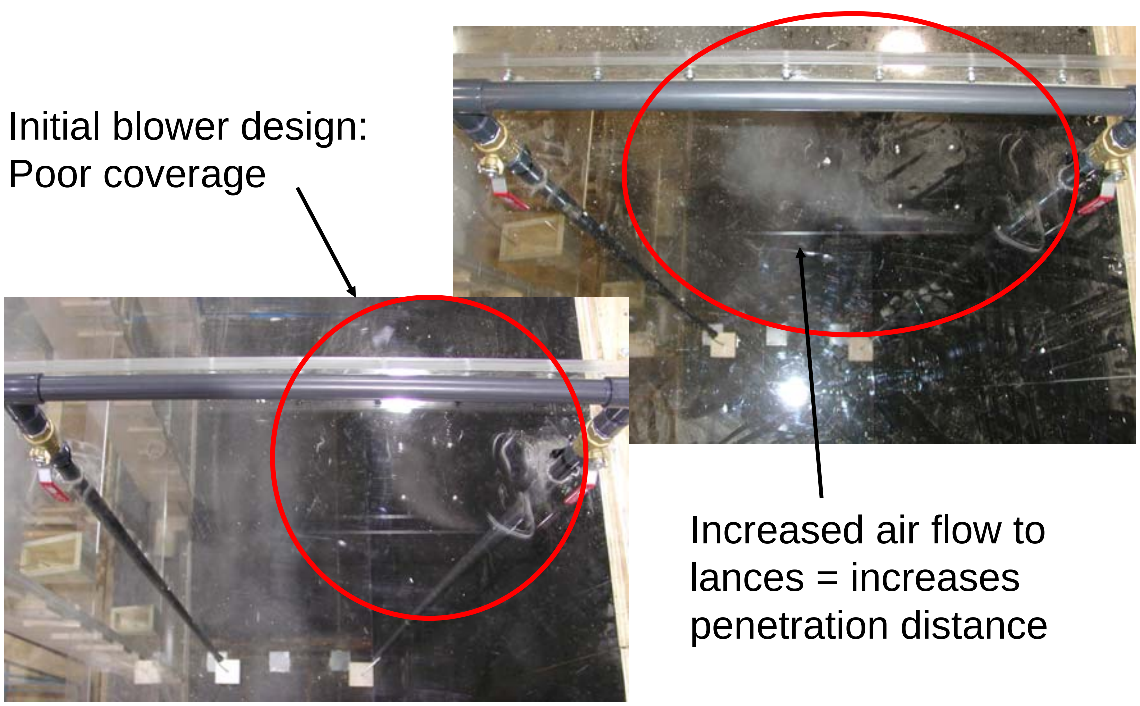


Figure 42. NELS physical modeling of plume penetration.

The NELS physical model suggests there are two issues with the current design of the Independence Unit 2 ESP box that may be contributing to particulate emissions. Only one of these issues directly relates to potential increases in emissions due to PAC injection. "The existing outlet plenum with no flow devices is a problem area by itself having high velocities along the top section of the last collection field and again causing particulate re-entrainment and opacity spiking" (NELS). This velocity distribution issue is evident in Figure 43.

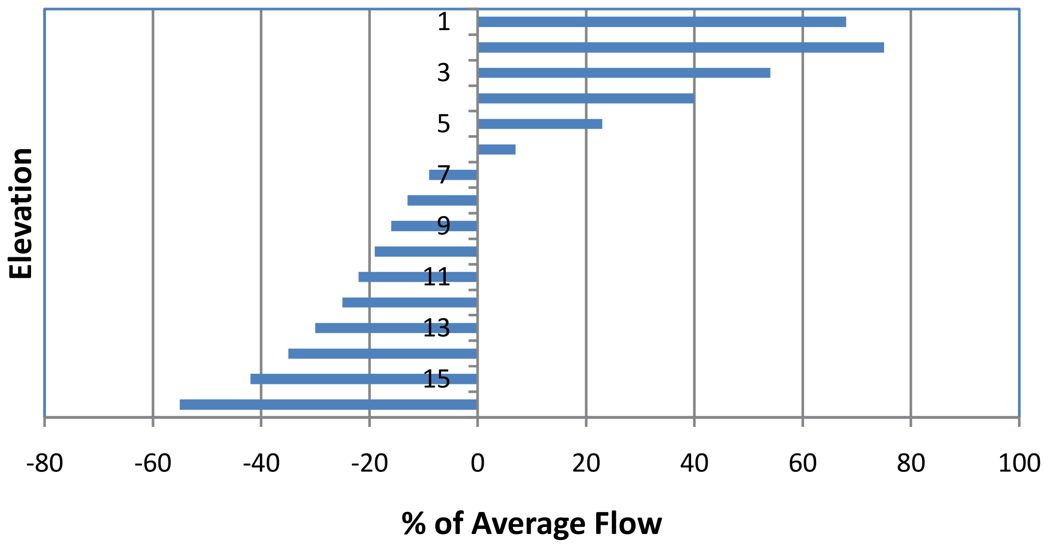


Figure 43. NELS physical modeling of ESP B B-7 outlet field exit.

Physical Modeling of Injection Grid

The modeling effort undertaken by ADA-ES included several injection concepts. In general, particle penetration results using single holes were consistent with NELS efforts as were those using commercial nozzles. At the penetration velocities desired, a simple hole pattern, whether arranged in a multi-hole vertical lance or arranged around a single cap, appeared to be the most functional.

Physical modeling in the ADA-ES lab, and supported by the data from NELS, indicated that because of poor sorbent penetration, sorbent may not have been reaching at least 30% of the ESP during high-load operation (Figure 44). On Figure 44, a sketch of the injection grid is shown with vertical lances on the left of the Figure. On the right, the lances are shown horizontally in bold with the top of the lance on the left and the bottom of the lance on the right. This convention is also followed in Figures 45 and 46. During low-load operation, the flow through the ESP is lower and the resulting sorbent penetration into the ESP is greater (Figure 45). The change in sorbent penetration from high- to low-load operation helps explain the limited removal observed during high load compared to low load during testing with the original grid design at Independence.

Models were conducted with nozzle orientation ranging from counter to co-current to control the penetration of sorbent across the ESP. As a result of these studies, the redesigned lance design incorporated two nozzles at each of four elevations along the length of each lance section. Three lance sections were used in each injection port to better control sorbent mass distribution. The nozzle orientation was varied along the length of each lance section to provide uniform penetration depth from top to bottom. Figure 46 shows the results of the physical model for sorbent penetration at high load using the redesigned injection grid system. The conveying air flow could also be adjusted to control the overall penetration depth. Varying the carrier air flow resulted in varying penetration depths during physical modeling but, as noted earlier, no significant change in mercury removal was noted as a function of carrier air flow during full-scale testing.

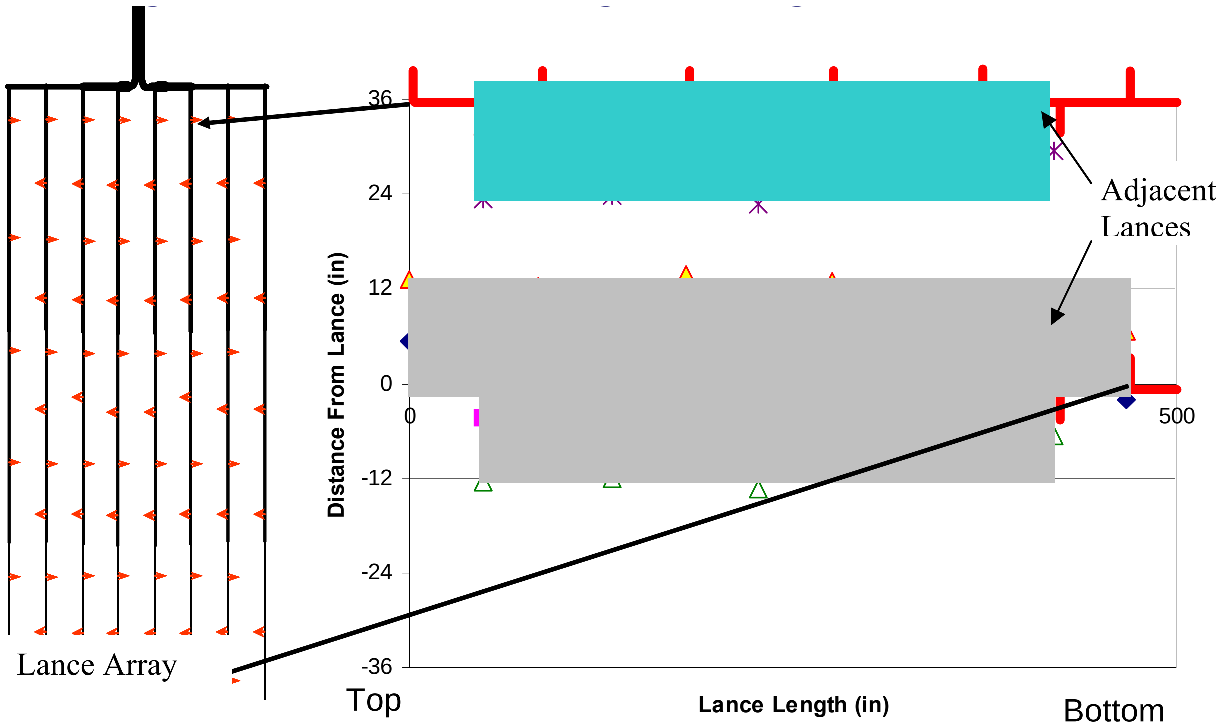


Figure 44. Carbon penetration at high load using the original grid design.

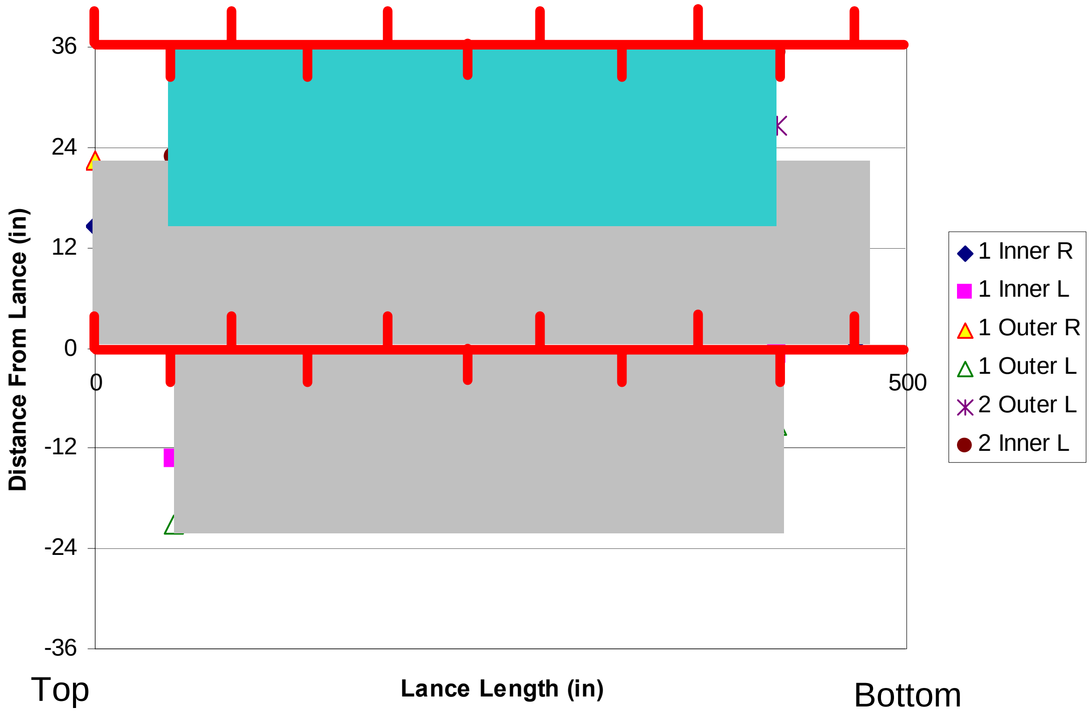


Figure 45. Carbon penetration at low load using the original grid design.

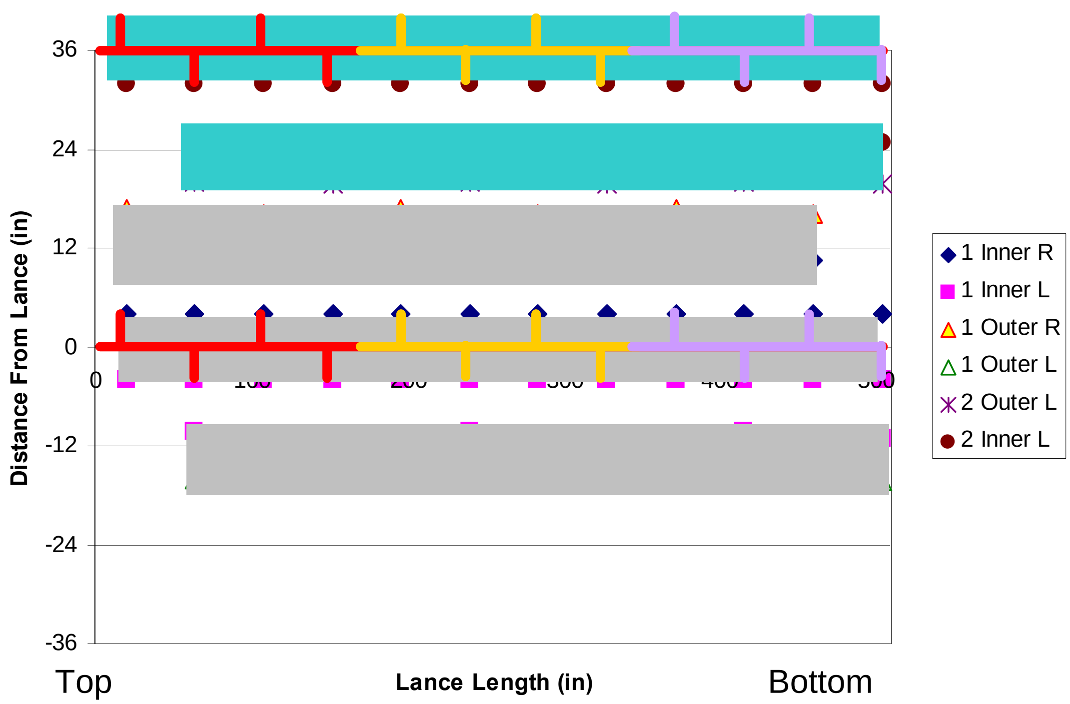


Figure 46. Carbon penetration at high load using the redesigned injection grid system.

Injection lance carbon distribution based on physical modeling conducted at ADA-ES were similar to CFD predictions developed by REI (Figure 47), with the nozzle furthest from the injection header (also the bottom of each lance section) demonstrating the highest mass loading. Several variations of a single multi-nozzle injection lance were tested, incorporating various hole sizes and lance section lengths. To minimize the maldistribution of sorbent along the height of the ESP, the lances were segmented into 3 sections. The mass loading results for the original lance are presented in Figure 47 and the corresponding results from the redesigned lance arrangement are given in Figure 48. Comparison of the mass distribution results shown in Figures 47 and 48 suggest a significant improvement in the sorbent distribution along the height of the ESP.

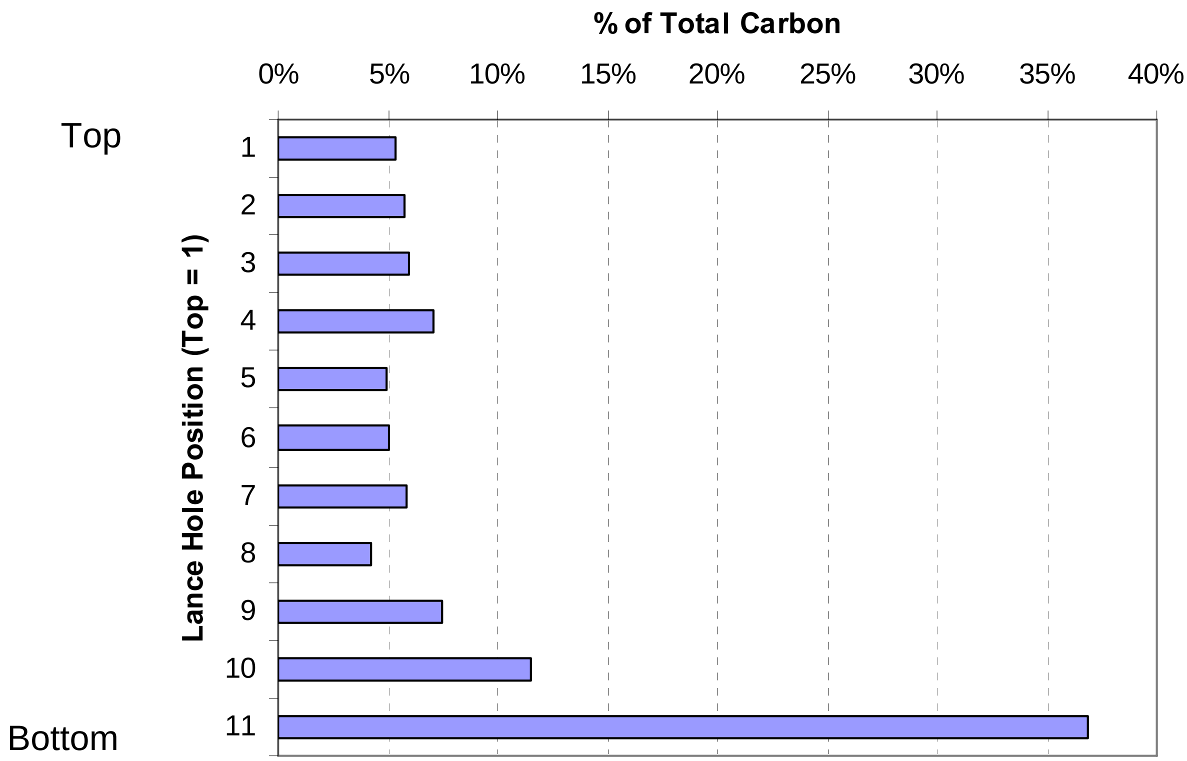


Figure 47. Physical model of carbon distribution from original lance.

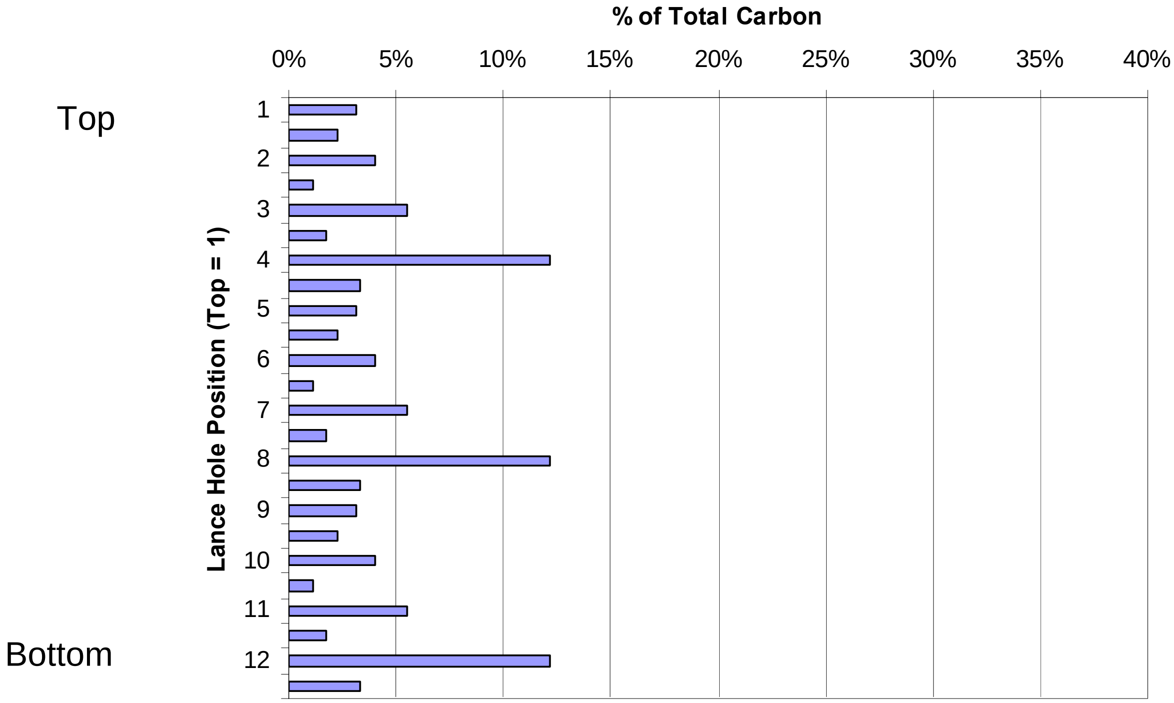


Figure 48. Physical model of carbon distribution from redesigned lance arrangement.

Using three lance sections instead of a long single lance (three sections with nozzles along 13 feet each, compared to one lance with nozzles along a length of more than 40 feet) provided a significant improvement in the vertical sorbent mass distribution. This resulted in higher mercury removal during the Parametric tests in 2007; however, the multiple holes were still prone to pluggage. A further refinement modeled and field-tested was the installation of a compressed air tap on the bottom of the lance. This tap could be used to both unplug the lance, if plugged, or if operated continuously, could alter the bias of the sorbent. With proper tuning, the bias could be shifted to allow an even (+/- 15%) sorbent flow through each nozzle. The air back pressure would have to be tuned to account for changes in ESP pressures and ambient conditions and plant load changed, but would result in more even flows. This was a functional concept, but resulted in a significantly more complex grid design than a passive grid. Consider that 1/16 of the Independence Unit 2 ESP, or 55 MW equivalent, required 24 lances installed into 8 ports. The treatment area was nominally 40 feet high by 10 feet wide. Treating the entire Unit 2 ESP with this grid design would require 384 separate lances. Rather than pursuing this design further, the design team began working towards a simpler design with lower maintenance and operating requirements. This effort was conducted outside of the DOE program.

Characterization of Process Solids and Liquids

Several types of process samples were collected during TOXECON II™ testing at Independence. Analyses conducted included ultimate, proximate, mercury and halogens for select coal samples, mercury analyses of most fly ash samples collected, and stability determinations of select fly ash samples through leaching tests. The LOI carbon content of several ash samples was also determined. Results from these analyses are presented below.

Grab samples of coal and fly ash collected throughout testing were analyzed for mercury content. Mercury concentrations in the coal samples can be used to estimate mercury concentration in the flue gas by assuming all of the mercury in the coal volatilizes and forms vapor-phase mercury. This value can be compared to the mercury concentration measured with the mercury S-CEM. Since the mercury S-CEM only measures vapor-phase mercury, the two values may not compare well if there is a significant fraction of particulate-phase mercury at the inlet to the ESP. Mercury concentrations in the fly ash samples can be used to estimate the amount of mercury being collected on the fly ash and removed from the vapor-phase.

Mercury Emissions (lb/TBtu) = $Hg_d F_c (1-B_{ws}) 100/\%CO_{2w}$

Where: Hg_d = Mercury Concentration (lb/dscf)
$F_c = 10^6[321\%C_d]/GCV_d$
B_{ws} = Moisture Fraction of flue gas
$\%CO_{2w}$ = Percent CO_2 in flue gas
%Cd = Percent carbon in coal from ultimate analysis (dry basis)
GCVd = Gross Calorific Value of coal from ultimate analysis, dry basis (BTU/lb)

Coal Analysis

Plant personnel collected coal samples daily throughout the evaluation. To collect a representative sample of the as-fired composition of the coal, samples were collected at the Unit 2 coal feeder belts upstream of the coal silos. Approximately 1-liter samples were collected and select samples were analyzed from each test period. These coal samples were typically collected midmorning during each test day to represent the coal fired 5 to 6 hours after collection. Therefore, a coal sample collected at 9 to 10 a.m. would match the coal combusted mid-afternoon.

A key criterion for this test program was to test at a site that burned 100% PRB coal; a criterion Unit 2 met as it normally burns 100% PRB coal. On several occasions during the testing period, however, the plant shifted to a 100% western bituminous coal from the ColoWyo mine for 2 to 3 days at a time. The impact of this alternate fuel source on plant operating conditions was evaluated as part of Entergy's goal to increase fuel supply reliability. The primary coal source during the test period was PRB from the North Antelope mine. Moisture levels for the "as received" samples were approximately 27% for the North Antelope coal and approximately 20% for the ColoWyo coal. The "as received" HHV Btu contents were 8750 BTU/lb and 9946 BTU/lb, respectively. For the purposes of this report, unless specifically noted, all results are based on the 100% PRB coal conditions.

Results from the ultimate, proximate, chlorine, fluorine, and mercury coal analyses during the two Baseline test periods and from Long-Term testing are presented in Table 12. Both coal analyses from Baseline testing represent results for North Antelope coal and were averaged. The table compares the results for coal burned during the Long-Term test phase with a ColoWyo coal sample collected on November 1, and an average of North Antelope coal samples on October 11, 13, 18, and 25. The chlorine content for all samples was very low. The sulfur levels for the North Antelope and ColoWyo are comparable. As indicated above, the heating value for the ColoWyo coal is higher than the North Antelope coal.

Table 12. Results from Baseline and Long-Term coal analyses (dry basis).

	Baseline Test Phases North Antelope August 17 and September 30, 2005	Long-Term North Antelope October 2005	Long-Term ColoWyo November 1, 2005
Element			
Hg (ng/g)	61.5	68.4	13.1
Cl (µg/g)	1.4	1.35	1.0
Br (µg/g)	37.3	6.3	11.0
F (µg/g)	--	78.0	100.0
Proximate			
Ash (wt%)	6.6	6.59	7.13
Volatile Matter (wt%)	43.68	43.24	38.84
Fixed Carbon (wt%)	49.73	50.18	54.03
Heating Value (BTU/lb)	12,083	12,009	12,415
Total Sulfur (wt%)	0.30	0.26	0.34
Ultimate			
Ash (wt%)	6.6	6.59	7.13
Carbon (wt%)	71.04	70.05	71.52
Hydrogen (wt%)	4.73	4.76	4.78
Nitrogen (wt%)	0.91	0.88	1.54
Total Sulfur (wt%)	0.30	0.26	0.34
Oxygen (by difference) (wt%)	16.43	17.47	14.69

Carbon and Mercury in Ash

The carbon and mercury content of several ash samples collected at Independence was analyzed and results are included in this section. The carbon content was estimated by comparing the weight difference between a dried sample and a sample heated to 800ºC for 2 hours. This is the typical analysis technique used to measure unburned carbon, or loss on ignition (LOI) content and the results are reported here as LOI in reference to the analysis technique. For samples containing activated carbon, LOI is primarily a measure of both the unburned carbon from the fuel and the activated carbon injected into the system. For very low levels of carbon, there can be a difference between the actual carbon content measured with a carbon analyzer and the change in weight from combustion using an LOI analysis, with the LOI analysis biased slightly high. LOI analysis should be a good representation of the carbon content of the ash during sorbent injection.

A summary of the LOI in fly ash samples collected during the 2005 Baseline (Figure 49 and Figure 50) and Long-Term tests is shown in Figure 51. LOI and mercury are shown together to highlight trends, if any, between native LOI carbon and mercury in the ash. The results are separated by hopper. It is clear that ash collected in the first collection field, which represents the majority of the Unit 2 ash, contains very little LOI carbon with all samples less than 0.25%. This is fairly representative of a well operating PRB PC boiler without low-NO_x burners.

The corresponding mercury in the ash for these samples is also fairly low, all less than 150 ng/g. A rough calculation of the fraction of mercury captured with the ash can be conducted as follows:

$$\text{Hg in ash/Hg in coal} = \frac{(AshHg)(CoalAsh)(ESPAsh)(Field1Ash)}{(CoalHg)}$$

Where:

AshHg = mercury content of ash (ng/g)

CoalAsh = fraction of ash in coal from Ultimate or Proximate analysis

ESPAsh = fraction of ash entering ESP (estimated at 85% for PC boiler)

Field1Ash = collection efficiency of Field 1 (estimated at 80%)

CoalHg = mercury content of coal (ng/g)

Using values from Table 12, at 150 ng/g mercury, the fraction of the mercury in the coal that is captured with the ash in the first field of the ESP is:

$$\text{Hg in ash/Hg in coal} = \frac{(150)(0.066)(0.85)(0.8)}{(61.5)} = 0.11$$

Thus, ash mercury concentrations less than 150 mg/g in the first collection field represent mercury capture of at most 11% of the incoming mercury, which is consistent with the SCEM measurements. Analysis of one sample from the second collection field indicated nearly 600 ng/g mercury in the ash. Using the approach outlined above, and estimating that the collection efficiency of the second field is also 80%, 600 ng/g mercury represents roughly 9% of the coal mercury as follows:

$$\text{Hg in ash/Hg in coal} = \frac{(600)(0.066)(0.85)(0.2)(0.8)}{(61.5)} = 0.09$$

Where (0.85)(0.2) is the fraction of ash exiting the first collection field. Each subsequent hopper represents a lower portion of the overall ash collected.

The LOI value in the 2005 Baseline samples in the first two collection fields ranged from 0.14 to 0.38. The highest LOI fraction was present in the last collection field (0.6 to 3.35%). It is fairly common to have higher fractions of carbon in the downstream collection hoppers. Recent research by Gerry Klemm of Southern Company[1] indicates that this is a result of lighter carbon particles "floating" out of the collection hoppers and into the downstream hopper following an ESP plate rapping cycle. Figure 50 indicates that the higher carbon fraction in the fourth field hoppers does not necessarily correspond to higher mercury concentrations. The field 4 trend shown in the figure suggests that the highest LOI. 3.5% corresponds to the lowest mercury concentration from the fourth field, 39 ng/g and the lowest LOI, 0.6%, corresponded to the highest mercury, 250 ng/g. Higher levels of native LOI often do not correlate with higher mercury concentrations in the ash. This is probably due to the characteristics of the carbon, such as particle size or surface morphology, that may affect the mercury capture potential. No analyses were conducted during this program to analyze the characteristics of the LOI carbon.

The mercury and LOI concentrations in the downstream fields on the test side of ESP B were much higher during the Long-Term test period. During the first half of the Long-Term test, carbon was injected upstream of the last collection field. Through October 21, PAC was injected between collection fields 3 and 4. The LOI and mercury concentrations in the test side third field hopper (hoppers 31 and 32) are elevated above baseline during this period, which could be either a carryover from Parametric testing or an indication that some PAC was blown into the upstream fields. It is interesting to note that after the injection location was moved upstream of the third collection field, the LOI in the hopper 3 ash increased significantly, but the mercury concentration did not show a correspondingly large increase. This suggests that significant carbon may have been removed before removing mercury from the flue gas. This could be an indication of the poor sorbent distribution discussed earlier in this report.

Another indication that the activated carbon may not have been as effective as expected can be seen in Figure 52. This graph shows the mercury to carbon ratio (calculated by dividing the Hg concentration by the LOI) for the four collection fields. As shown, the lowest mercury to carbon ratio, less than 20 ppm, was in the field 3 ash collected when PAC was injected upstream of field 3. The next lowest ratio is the field 4 ash when PAC was injected upstream of field 4. Both are lower than the average ratio of mercury to native LOI carbon in fields 1 and 2, 58 ppm. For comparison, the ratio of mercury to ash in the TOXECON™ baghouse at Presque Isle Power Plant during carbon injection in 2007 ranged from 35 to 80 ppm.[2]

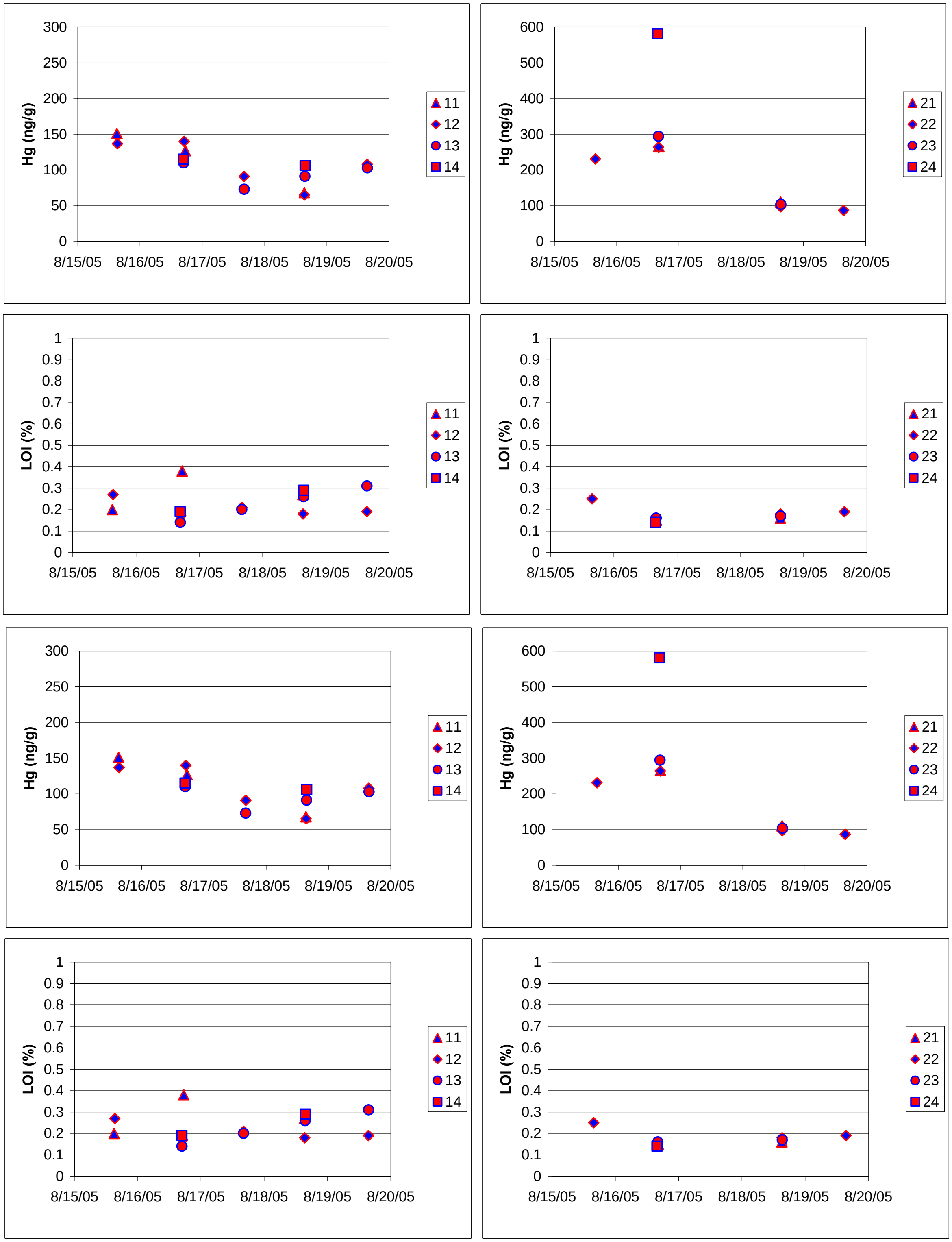


Figure 49. Baseline Mercury and LOI of fly ash samples collected from B-ESP hoppers on Test and Control (Ctrl) sides of the ESP during 2005 testing.

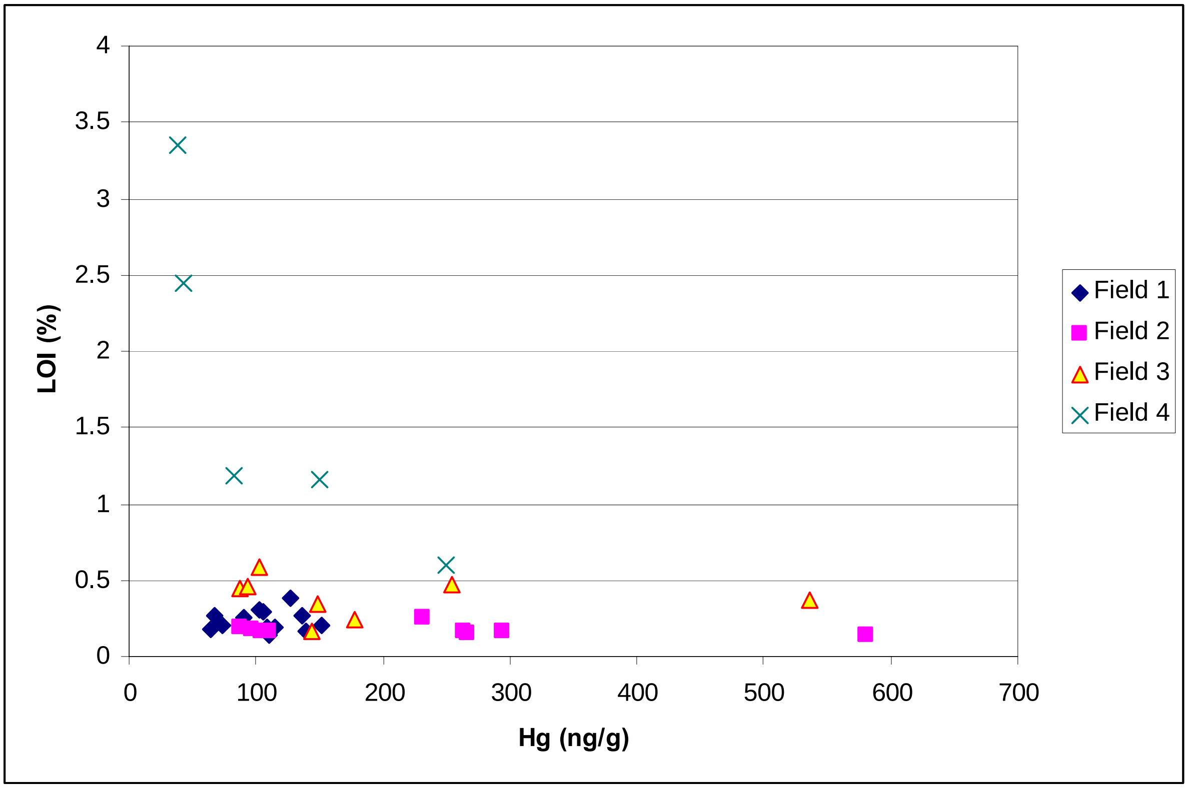


Figure 50. Mercury and LOI in hopper ash samples collected during Baseline testing.

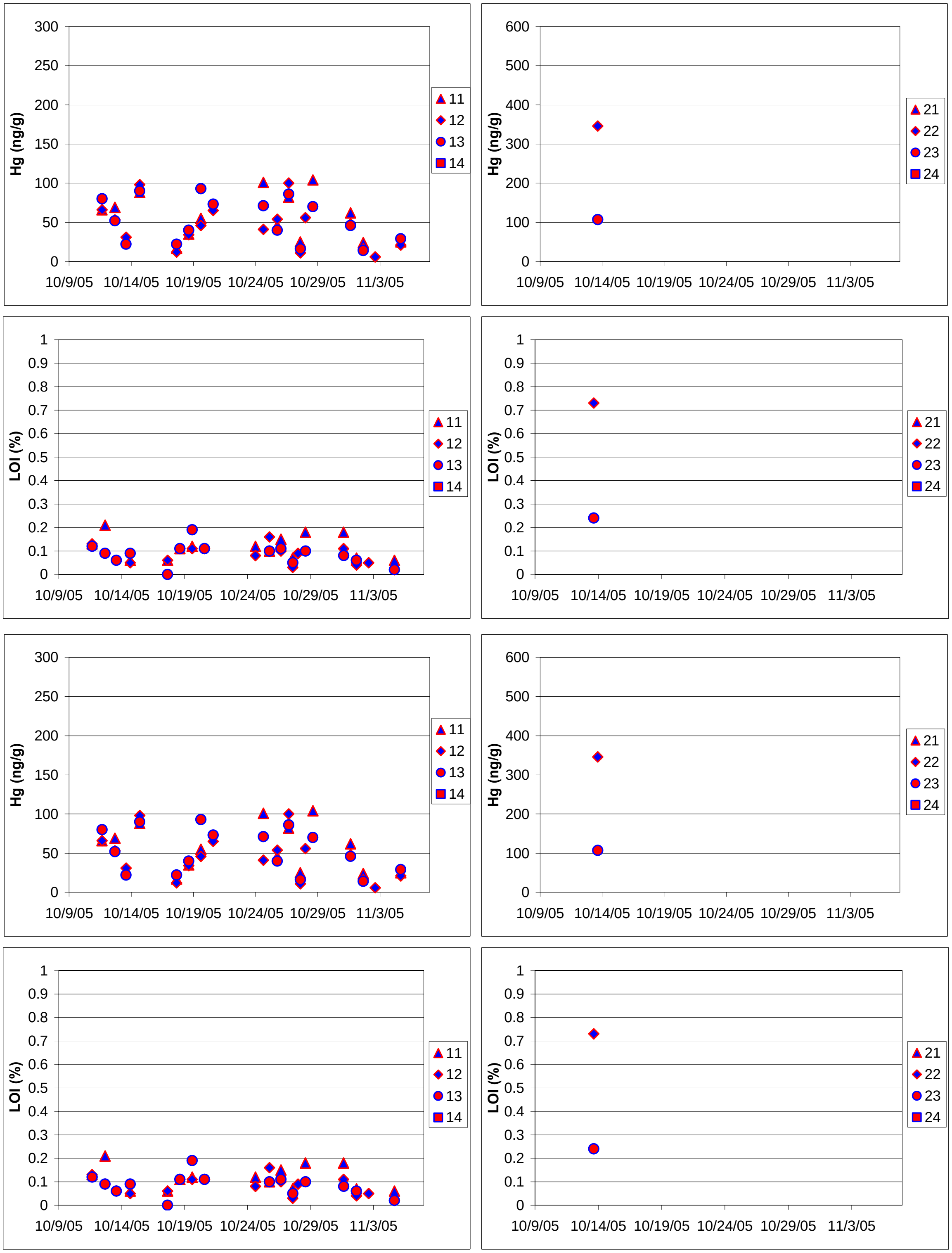


Figure 51. Long-term Mercury and LOI of fly ash samples collected from B-ESP fields on Test and Control (Ctrl) sides during 2005 testing when Colo Wyo was burned. DARCO® Hg-LH was injected either mid-box (i.e., between the 2nd and 3rd set of fields on the Test side) or rear-box (i.e., between the 3rd and 4th set).

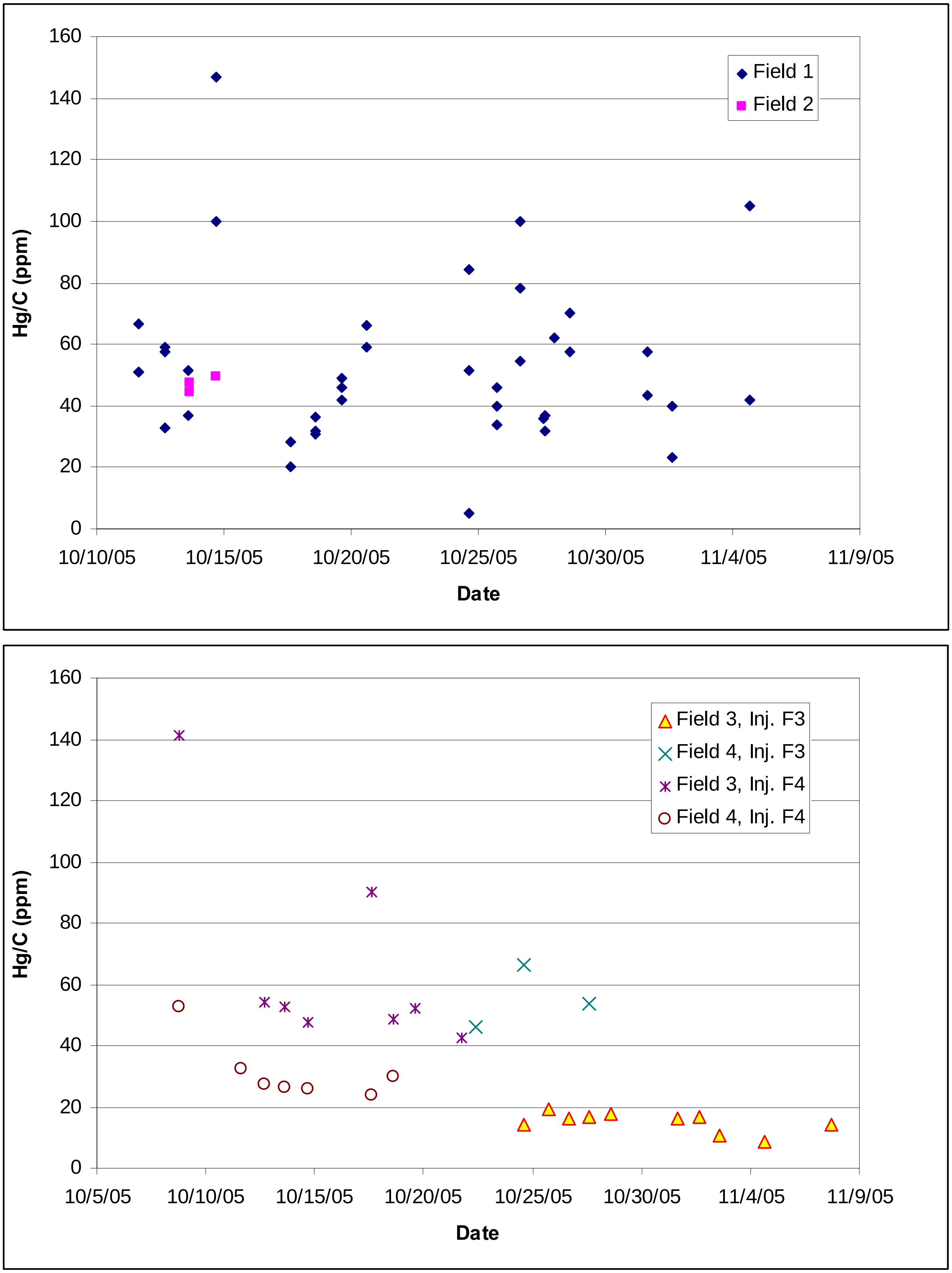


Figure 52. Mercury normalized to carbon content for hopper ash samples collected during Baseline testing.

Leaching Stability (Hg, Other Metals, and Halogens)

As part of the coal byproduct analysis, select ash samples were collected during the Baseline and Long-Term testing phases to determine the stability of mercury, bromine, arsenic, selenium, chlorine, fluorine, and iodine. Two leaching procedures were conducted: Method 1311, Toxicity Characteristic Leaching Procedure (TCLP), and the Synthetic Groundwater Leaching Procedure (SGLP). The TCLP procedure measures metal mobility, primarily As, Ba, Cd, Br, Se, and Ag, in a sanitary landfill.

The TCLP extraction fluid recipes were developed by computer modeling to simulate a worst-case scenario where the waste is co-disposed with municipal solid waste. For highly alkaline samples, such as those from Independence, a solution with a pH of 4.93, buffered using sodium hydroxide, is used. TCLP is the only leaching procedure approved for characterizing hazardous waste under the Resource Conservation and Recovery Act **(**RCRA).

The SGLP procedure was developed by Debra Pflughoeft-Hassett at EERC to better simulate the pH of groundwater to determine if mercury will leach from the samples under conditions designed to simulate actual field conditions, and addresses the incorporation of species into insoluble molecular matrices in a more static and arid environment . The SGLP consists of 100g sample dissolved into 2000 milliliters of distilled deionized water (or synthetic ground water) to achieve a liquid-to-solids ratio (L/S) of 20:1. The sample is rotated end-over-end, at 30 revolutions per minute, for 18 hours. The leachate is then filtered to remove all solids greater than 0.45 micrometers. For 30-day samples, the above treatment process is repeated.

The SGLP results for fly ash collected during Long-Term testing from the front field hoppers as well as the mid-ESP hoppers are presented in Table 13. An analysis of each element contained in the sample is also included in Table 13 as “total in sample.” The percent of each element leaching from the samples is provided in Table 14.

The TCLP results of one of the Long-Term and Baseline testing samples are provided in Table 15.

Since mercury concentrations were below the detection limit of the primary analysis laboratory, leachate was sent to Frontier GeoSciences Inc. for a trace level analysis. The FGS results are the mercury results posted in Table 13. The mercury concentrations were 3.56 µg/g in the test hopper and 0.14835 µg/g on the control side hopper. A very small amount of arsenic leaching was measured, but the levels in most cases are near the detection limit, the exception being the baseline control side SGLP and TCLP results performed on the Long-Term test side and the baseline control side hoppers where the value is factor of 5 and 6 times higher respectively. For both the 18-hour and 30-day leach, bromine in the leachate was higher for Long-Term test. This is expected since the test side sample was collected while bromine-treated activated carbon was being injected into the system.

Table 13. SGLP results from Independence (mg/L) during Long-Term testing while injecting mid-ESP.

Test Period	Long-Term			Long-Term		
ID	3926			3923		
Location	Hopper B-32			Hopper B-11		
	Downstream Sorbent Injection			Upstream Sorbent Injection		
Date	10/24/05			10/24/05		
	Total in Sample (μg/g)	18-hour (μg/g)	30-day (μg/g)	Total in Sample (μg/g)	18-hour (μg/g)	30-day (μg/g)
As:	16	< 0.01	< 0.01	120	0.08	< 0.01
Br:	24,000	890	860	< 20	2.68	1.88
Hg:	3.560	7.76E-6	5E-6	0.14835	2.47E-5	5.86E-6
Se:	17	0.02	0.03	5	< 0.01	0.01
Cl:	8000	14	12	< 100	< 1	< 1
F:	2000	1.48	4.31	27	< 0.02	0.84

Table 14. Percent of "Total in Sample" element concentration leaching from ash sample.

Test Period	Long-Term		Long-Term	
ID	3926		3923	
Location	Hopper B-32		Hopper B-11	
Date	10/24/05		10/24/05	
	18-hour	30-day	18-hour	30-day
As:	< 0.63%	< 0.063%	0.07%	< 0.01%
Br:	4%	4%	< 13.4%	9.4%
Hg:	0.0002%	0.18%	0.016%	0.004%
Se:	0.12%	0.18%	< 0.2%	0.2%
Cl:	0.2%	0.2%	< 1%	< 1%
F:	0.074%	0.22%	< 0.07%	3.11%

Table 15. TCLP results from Independence (mg/L).

Test Period	Baseline	Long-Term
ID	3564	3924
Location	Hopper B-12	Hopper B-12
Date	8/15/05	10/24/05
As	0.05	0.06
Hg	< 0.0002	< 0.0002
Se	0.05	0.05

Balance-of-Plant-Impacts

In conjunction with the mercury removal testing at Independence, the second parameter of concern was the potential of the TOXECON II™ configuration to affect other balance-of-plant issues. The primary concern was whether injecting PAC within the ESP would effect the operation of the ESP and the subsequent particulate emissions. Since the ESP collects the majority of the ash in the first fields, the ash loading in the rear ESP fields is significantly less than in the first fields. In the case of Independence, the first two fields remove 96% of the incoming fly ash based on data collected from the Neundorfer ash collection data system. Thus, the collection efficiency of the rear ESP fields is more dependent on the properties of the sorbent/ash mixture, rather than just the ash because the sorbent comprises a significant fraction of the total mixture. As discussed in the section on byproduct analysis, the carbon content of the third collection field increased by 20 to 30% when injecting using the mid-ESP injection grid, indicating that the particulate load to the third collection field increased by approximately 30 to 40%, since DARCO® PAC contains nominally 30% ash. The particulate loading percentage was higher when injecting in the rear grid due to the lower levels of ash in the flue gas downstream of three collection fields. This mixture could have a significantly different resistivity than ash alone, which could affect collection efficiency. As discussed previously, carbon may migrate from hopper to hopper because of the density difference between the carbon and the ash. Also, sorbent injection in the mid-ESP will increase the particulate loading in the rear fields, which can further affect total particulate exiting the fields.

ESP Operation and Particulate Emissions

Particulate emissions were monitored during testing at Independence using three techniques: periodic EPA Method 5 and 17 measurements (Appendices D1–5), TEOM Series 7000 continuous particulate monitor measurements, and CPM 5000 measurements. Stack opacity was also monitored, but was not as useful because only 1/32 to 1/8 of the Unit 2 flow was treated with PAC. The TEOM Series 7000 was used periodically through the second round of Parametric testing until weather-related equipment problems were encountered. When compared against a Method 5 on the outlet duct during Baseline test period, the TEOM Series 7000 was reading within 10% of the Method 17 results. These measurements were not collected concurrently because the TEOM Series 7000 was removed during Method 5 measurements to allow a traverse of the duct.

<u>Baseline ESP Performance</u>

Stack opacity and ESP parameters such as particulate emissions, power levels, and spark rates during the Baseline test series were of interest in establishing benchmarks against which the performance of the Parametric and Long-Term tests could be measured. Recall that the ESP B-box electrical field B-7 was non-operational during the August 2005 test period and well into September 2005. Figure 53 depicts the relationship between the unit load and opacity during the September 2005 Baseline period.

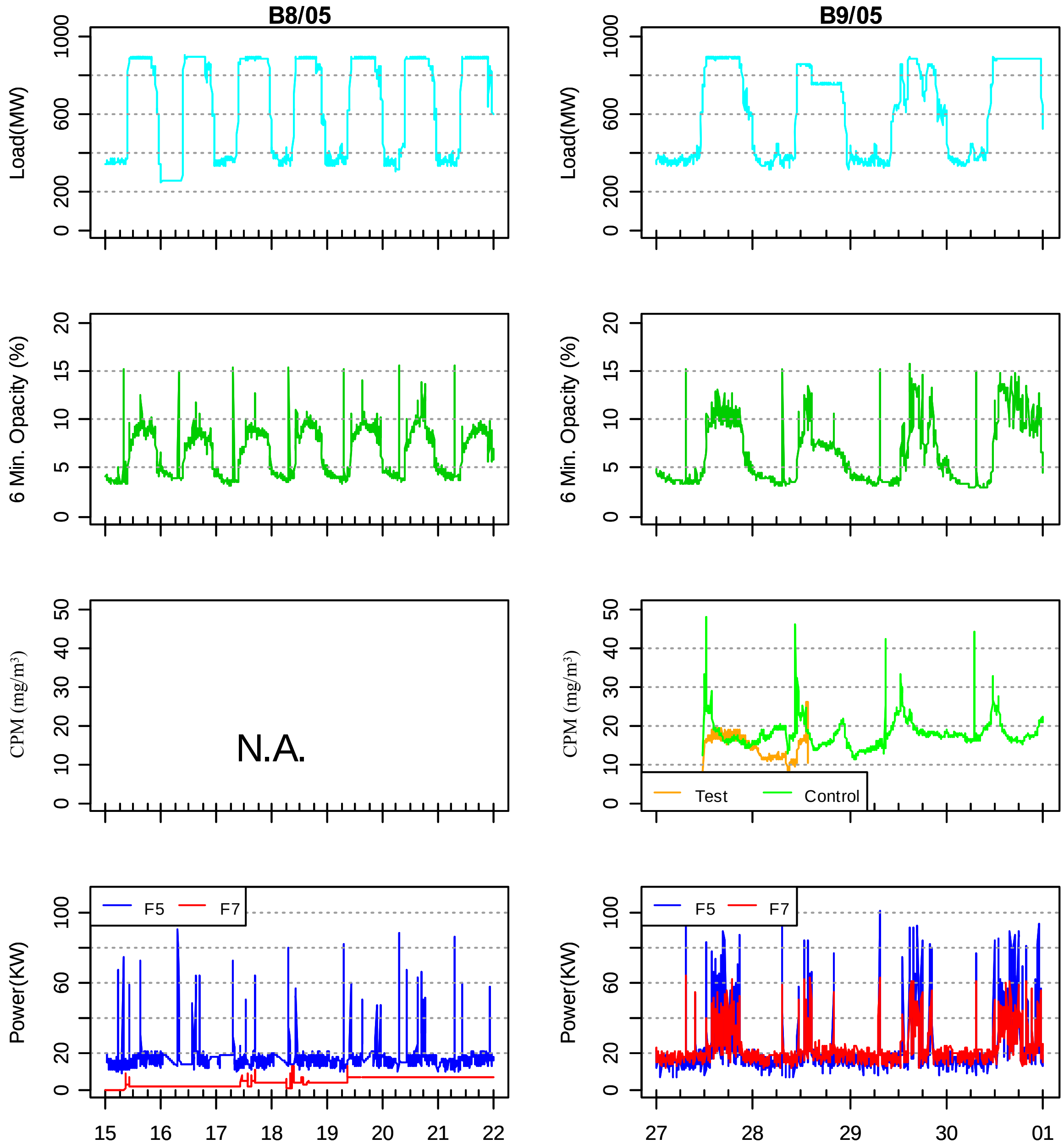
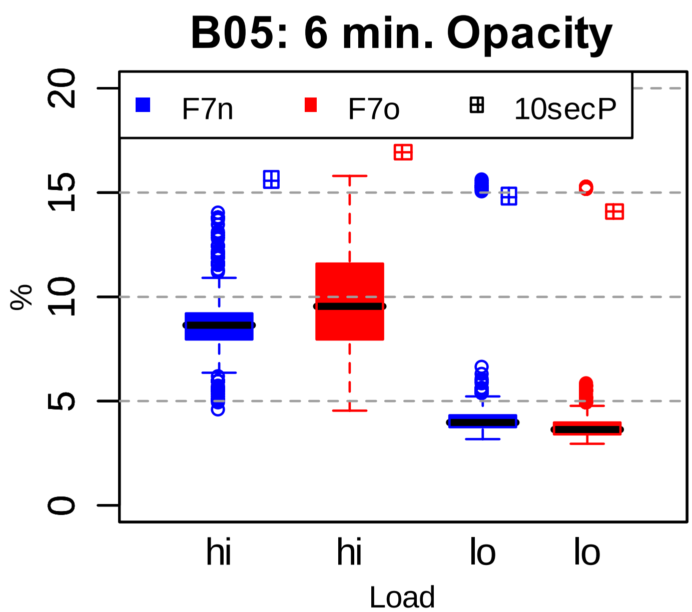


Figure 53. ESP operation and (6-minute) opacity during August and September 2005 Baseline testing. Opacity represents stack data.

Figure 54 summarizes the baseline 6-minute stack opacity averages at high (> 750 MW) and low (< 450 MW) boiler loads during round I (August 2005, F7 down) and round II (September 2005, F7 up). During both rounds, opacity was clearly higher during high boiler loads. Similar trends are evident in the average CPM values shown in Table 16.



Average 6 Min. Opacity (%)	
Aug 05: overall	6.6 ± 2.3
Sept 05: overall	6.5 ± 3.3
Aug 05: > 750 MW	8.6 ± 1.1
Aug 05: < 450 MW	4.2 ± 1.1
Sept 05: > 750 MW	9.8 ± 2.2
Sept 05: < 450 MW	3.8 ± 1.1

(a) **(b)**

Figure 54. (a) Box whisker plots of stack opacity (6-minute) percentages during Baseline 2005 testing when B-F7 was non-operational (F7n, August)) and operational (F7o, September) at boiler loads > 750 MW (hi) and < 450 MW (lo). Also shown are peak 10-second opacity (10secP) percentages for the same conditions. (b) The same data shown as averages.

Table 16. Average CPM values at ESP B outlet duct on the Test and Control Sides during September 2005 Baseline testing.

	ESP B Test Side ($\mu g/m^3$)	**ESP B Control Side ($\mu g/m^3$)**
Sept 05: Overall	15 ± 3.2	18 ± 3.7
Sept 05: > 750 MW	17 ± 2.2	19 ± 3.9
Sept 05: < 450 MW	12 ± 1.4	16 ± 3.0

EPA Method 17 test results during the August 2005 Baseline test period are summarized in Table 17. As seen in the table, the results indicate that the precipitators at Independence are highly efficient, removing over 99% of the particulate matter entering the ESP B precipitator box. The full details of the results are included in Appendix D.

Table 17. EPA Method 17 results for Unit 2 during Baseline testing August 17–18, 2005.

	ESP B Inlet Duct	ESP B Outlet Duct	
Run #	**gr/dscf**	**gr/dscf**	**% Decrease**
1	1.78	0.01	99.4
2	1.51	0.01	99.2
3	1.84	0.01	99.3
Average	1.71	0.01	99.3

The power in ESP B-box rear electrical fields for the same high and low load conditions are shown in Figure 55. As seen in these figures, the last field on the control side of ESP B-box (F8) was consistently higher than the other rear fields regardless of load or round of recording. The average power levels in all electrical fields on the Test side of ESP B-box during both rounds are summarized in Table 18. Recall that the T/R set on ESP B field 3 (F3) had a long-term condition affecting its output. As seen in the table, it had a relatively low power level. Moreover, it would inconsistently power up and down throughout testing without detectable impact on performance relative to TOXECON II™ evaluation. The table also indicates that the average power level for the first and fourth test side electrical fields was higher during round II than for round I, and that the difference in power between high and low loads for these fields was larger. Recall that mercury speciation was also slightly higher during round II than round I. The theoretical relationship to which speciation changes are attributable across an ESP is the presence of ozone resulting from "back corona" effects. Table 18 would indicate that there is potential for "back corona" to be occurring due to the higher power levels during the second round of Baseline testing.

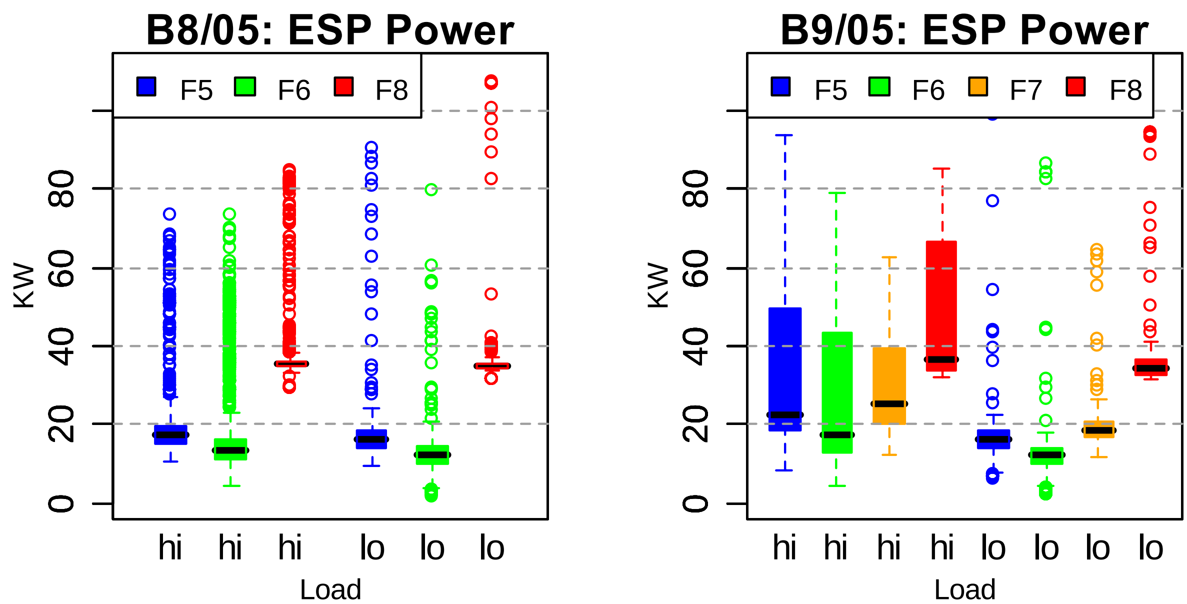


Figure 55. Box-whisker plots of power in ESP B-box rear electrical fields during August and September 2005 Baseline Testing. F5 and F6 are the third fields on the test and control sides, respectively; F7 and F8 are the last fields on the test and control sides, respectively. Plot contrasts power levels when boiler load is > 750 MW (hi) and < 450 MW (lo).

Table 18. Test-side ESP B average power levels during Baseline testing.

Test	F1 KW	F3 KW	F5 KW	F7 KW
Aug 05: Overall	19 ± 7	14 ± 8	18 ± 8	4 ± 3
Sept 05: Overall	27 ± 18	8 ± 3	24 ± 17	24 ± 10
Aug 05: > 750 MW	20 ± 6	19 ± 7	19 ± 8	5 ± 2
Sept 05: > 750 MW	33 ± 22	6 ± 2	30 ± 20	27 ± 12
Aug 05: < 450 MW	17 ± 8	9 ± 5	17 ± 8	4 ± 3
Sept 05: < 450 MW	19 ± 8	9 ± 4	17 ± 8	19 ± 6

The average spark rate during Baseline testing for the last two pairs of electrical fields in the ESP B-box is given in Figure 56.

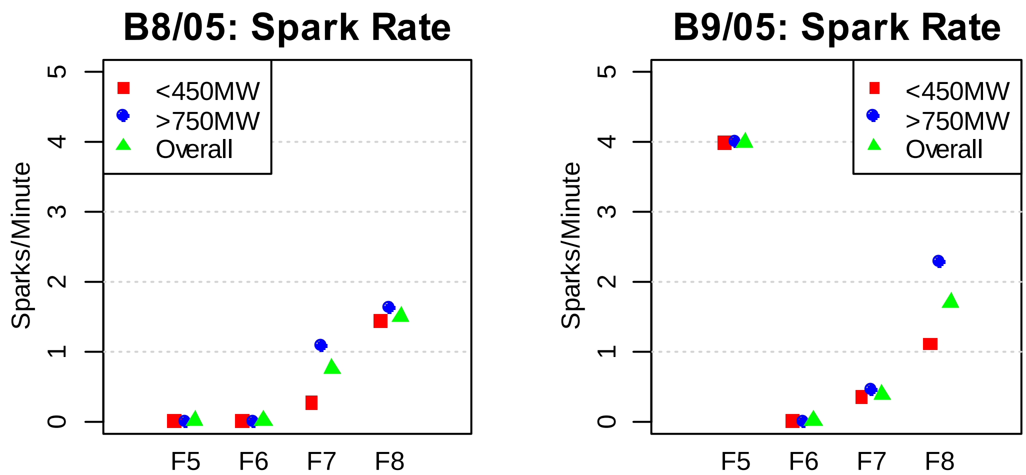


Figure 56. Average Spark Rate in ESP B-box electrical fields during 2005 Baseline testing. F5 and F6 are the third fields on the test and control sides, respectively; F7 and F8 are the last fields on the test and control sides, respectively. Plot contrasts overall spark rates with those when boiler load is at high loads (> 750 MW) and low load (< 450 MW).

Parametric ESP Performance

Trend charts of ESP performance during the 2005 Parametric test period are shown in Figure 57 through Figure 70. Each sorbent tested is shown in a separate figure to facilitate examination of the correlation between ESP power levels, sorbent injection, and plant opacity and Unit 2 B particulate emissions (from the CPM monitor). The data indicate that during the August and September tests, injection of any sorbent resulted in both opacity and CPM spikes. Although PAC was injected into only 1/8 of Unit 2, each time the final field was rapped during August and September while PAC was injected into either field 5 or 7, the spikes were clearly visible on the stack opacity.

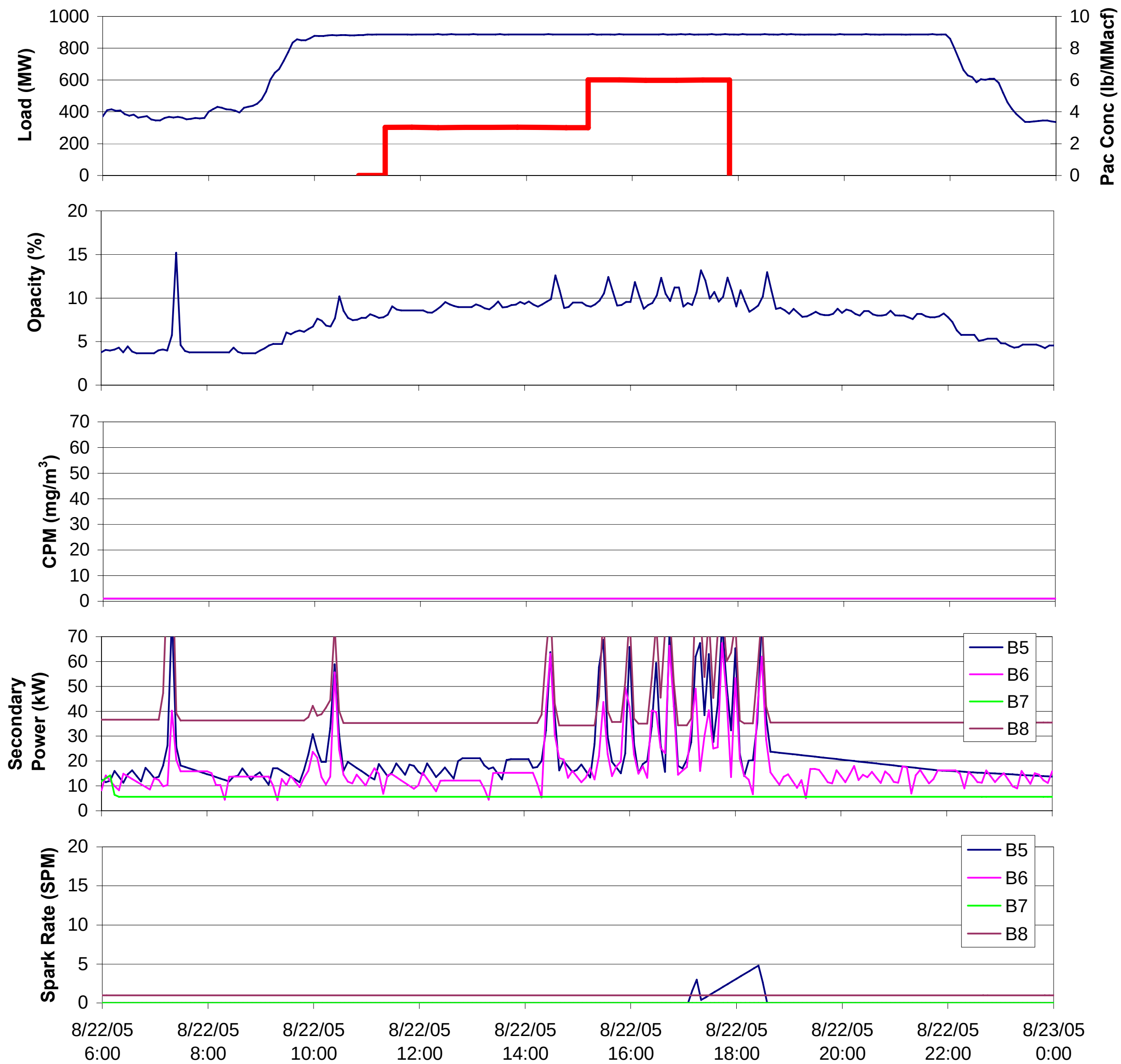


Figure 57. Operating trends during DARCO® Hg injection upstream of field 5.

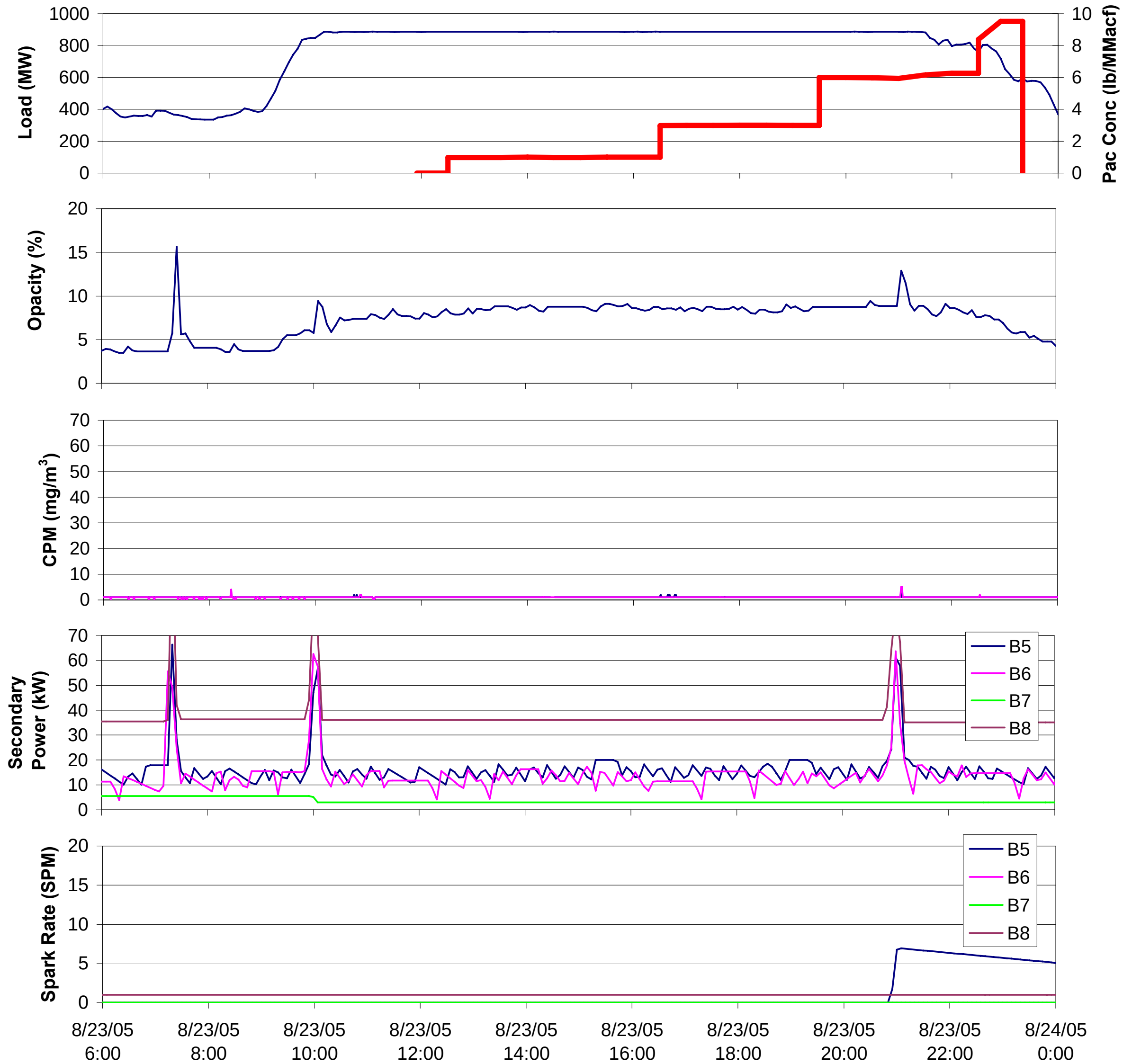


Figure 58. Operating trends during DARCO® Hg-LH injection upstream of field 5.

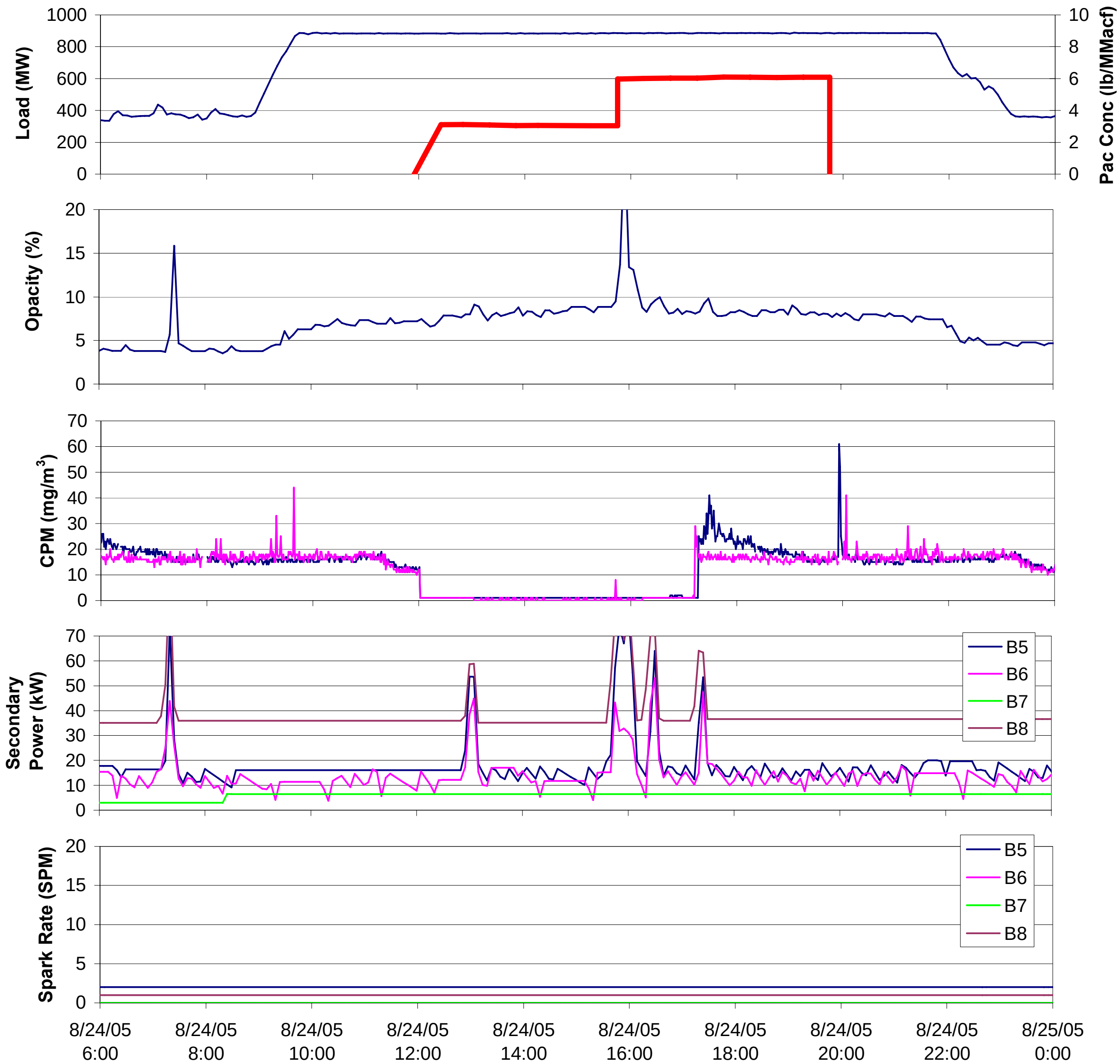


Figure 59. Operating trends during DARCO® E10 injection upstream of field 5.

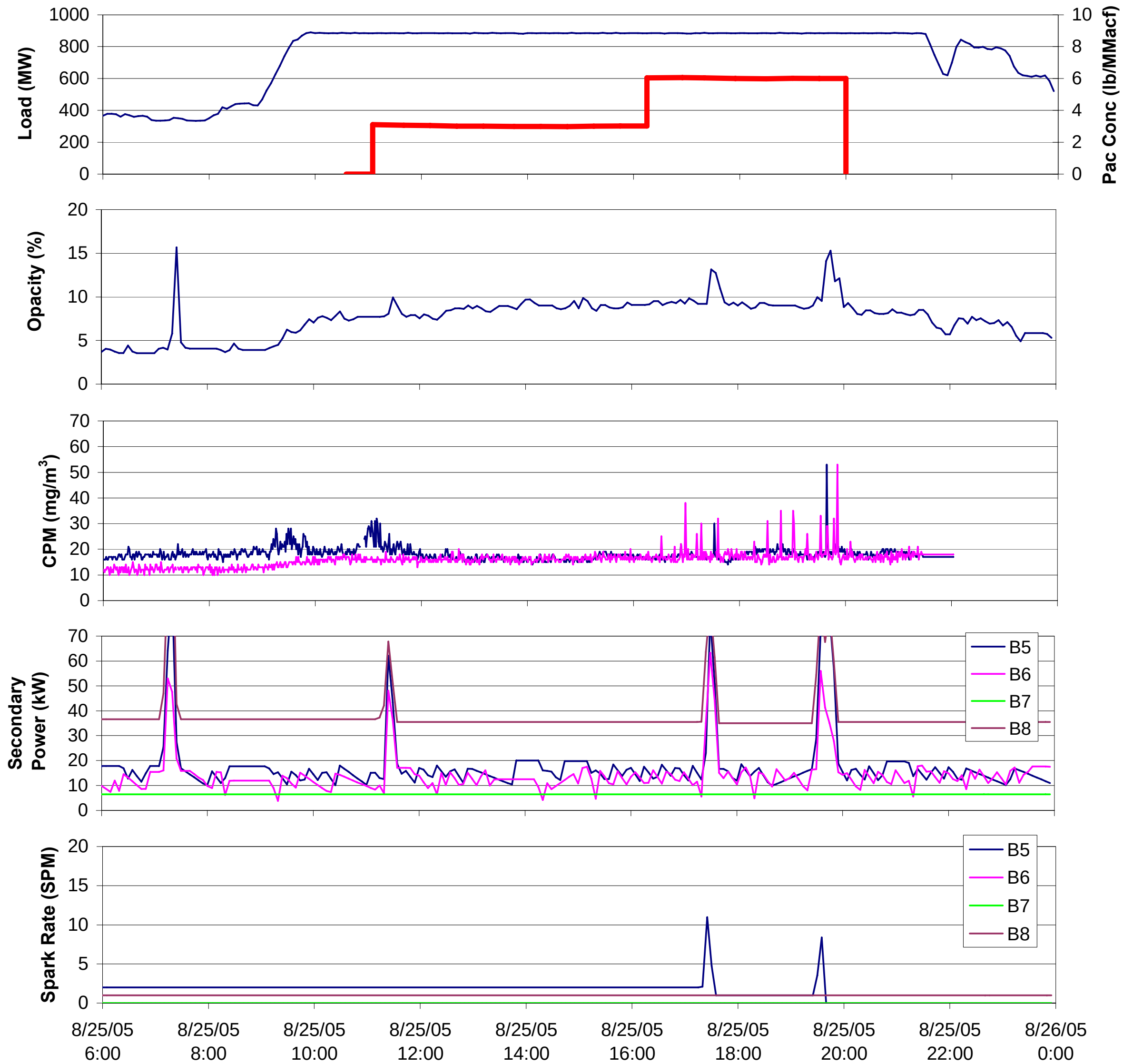


Figure 60. Operating trends during DARCO® E11 injection upstream of field 5.

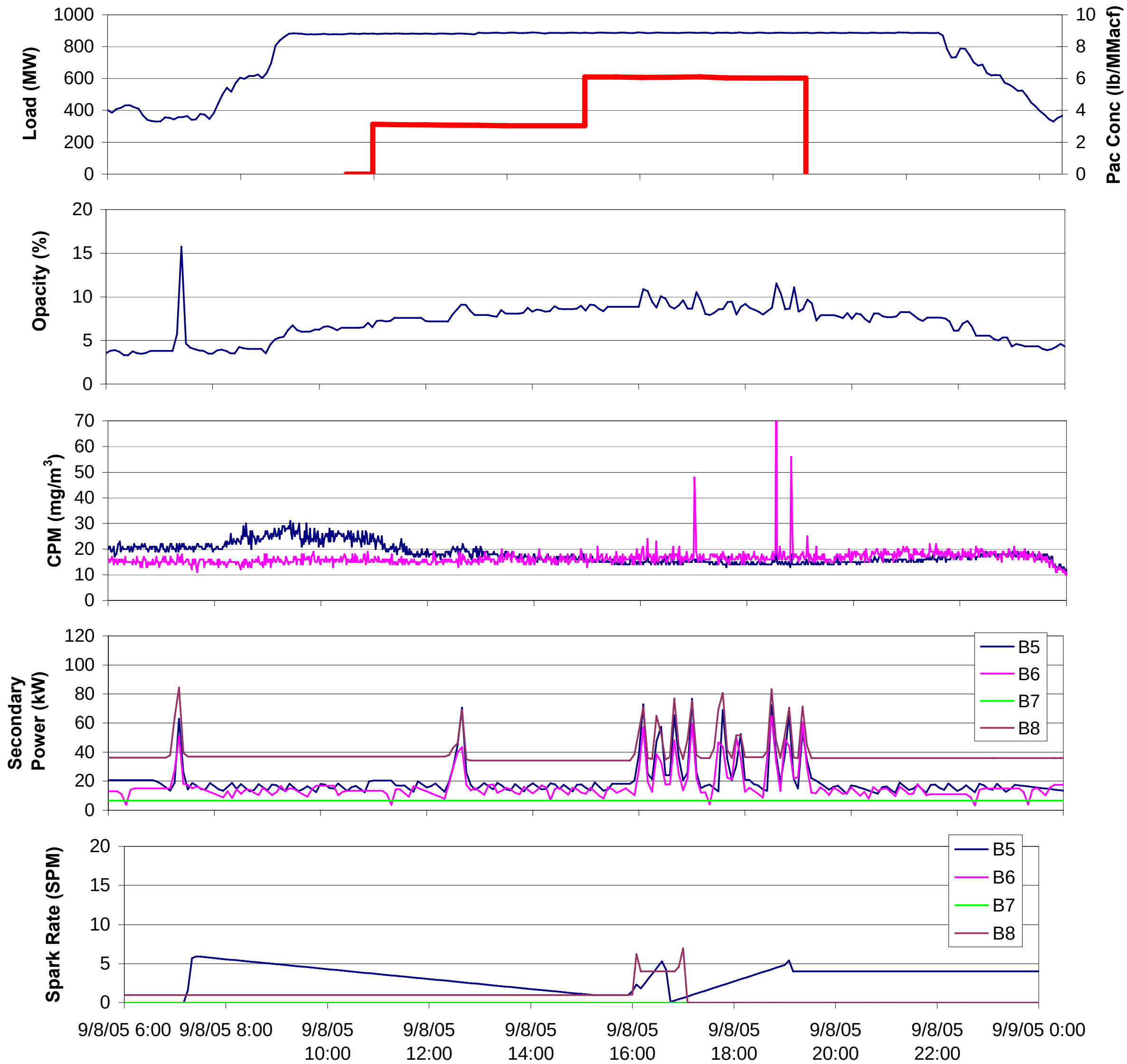


Figure 61. Operating trends during DARCO® Hg-LH injection upstream of field 5.

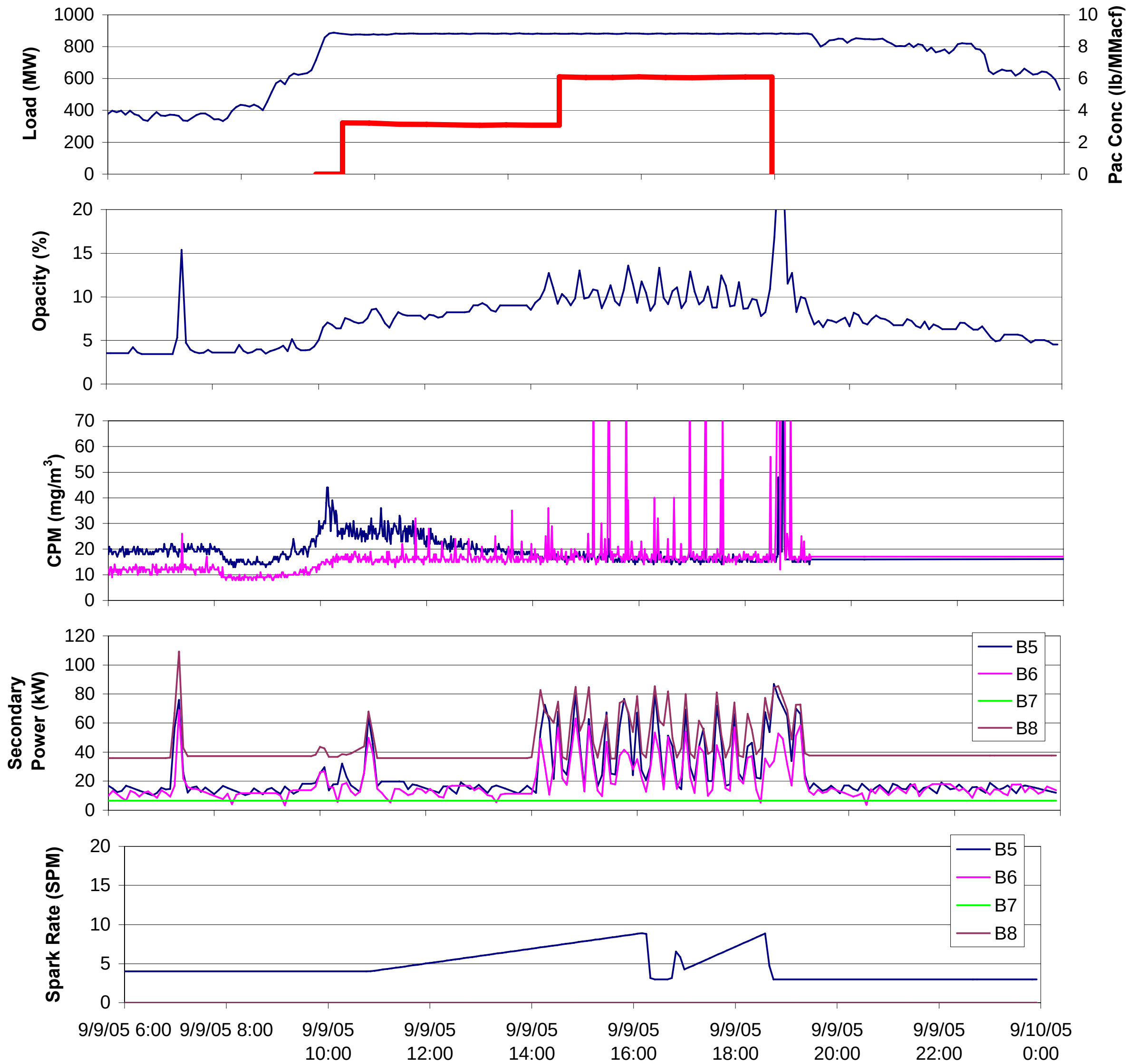


Figure 62. Operating trends during DARCO® Hg injection upstream of field 5.

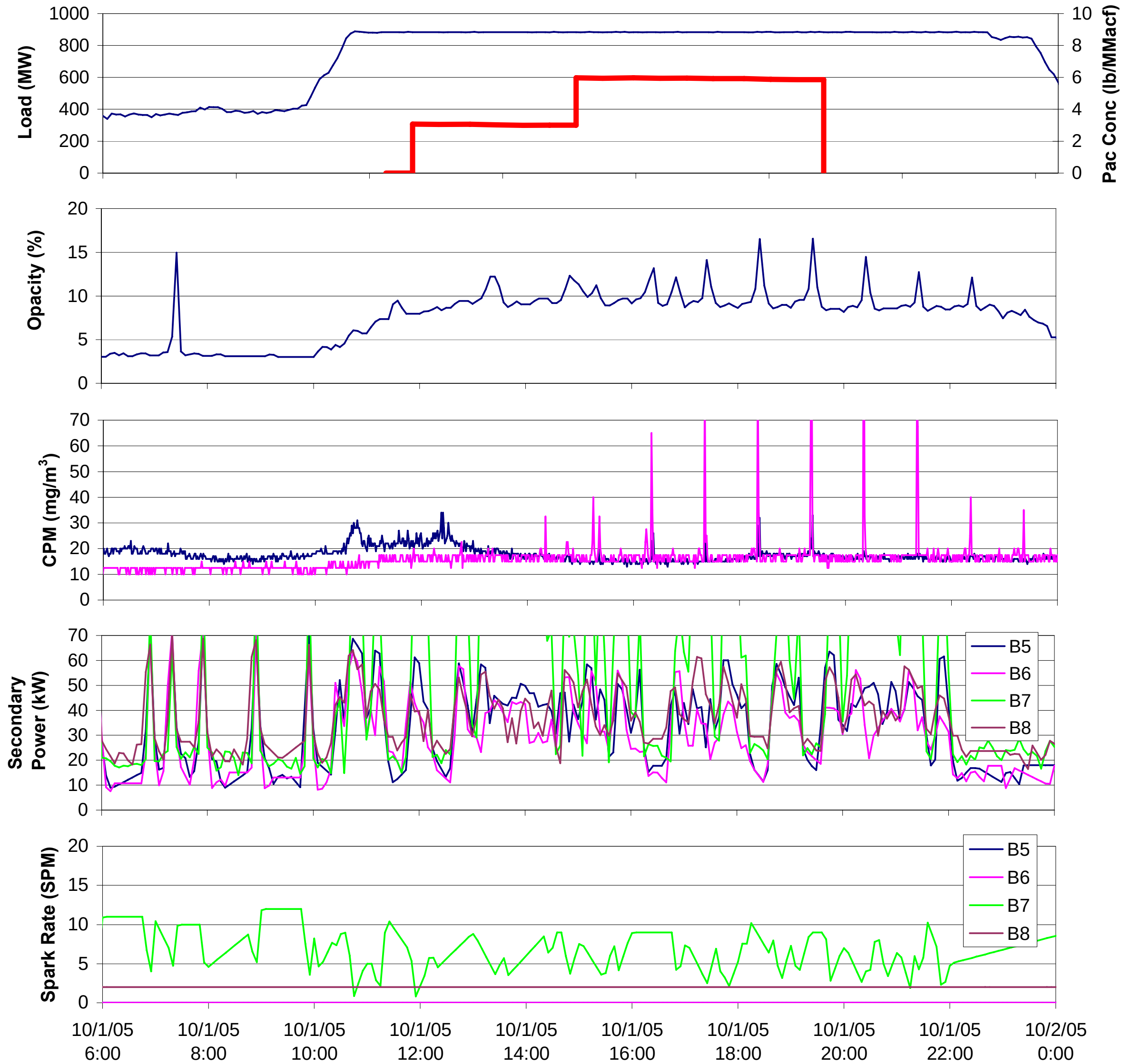


Figure 63. Operating trends during DARCO® E10 injection upstream of field 7.

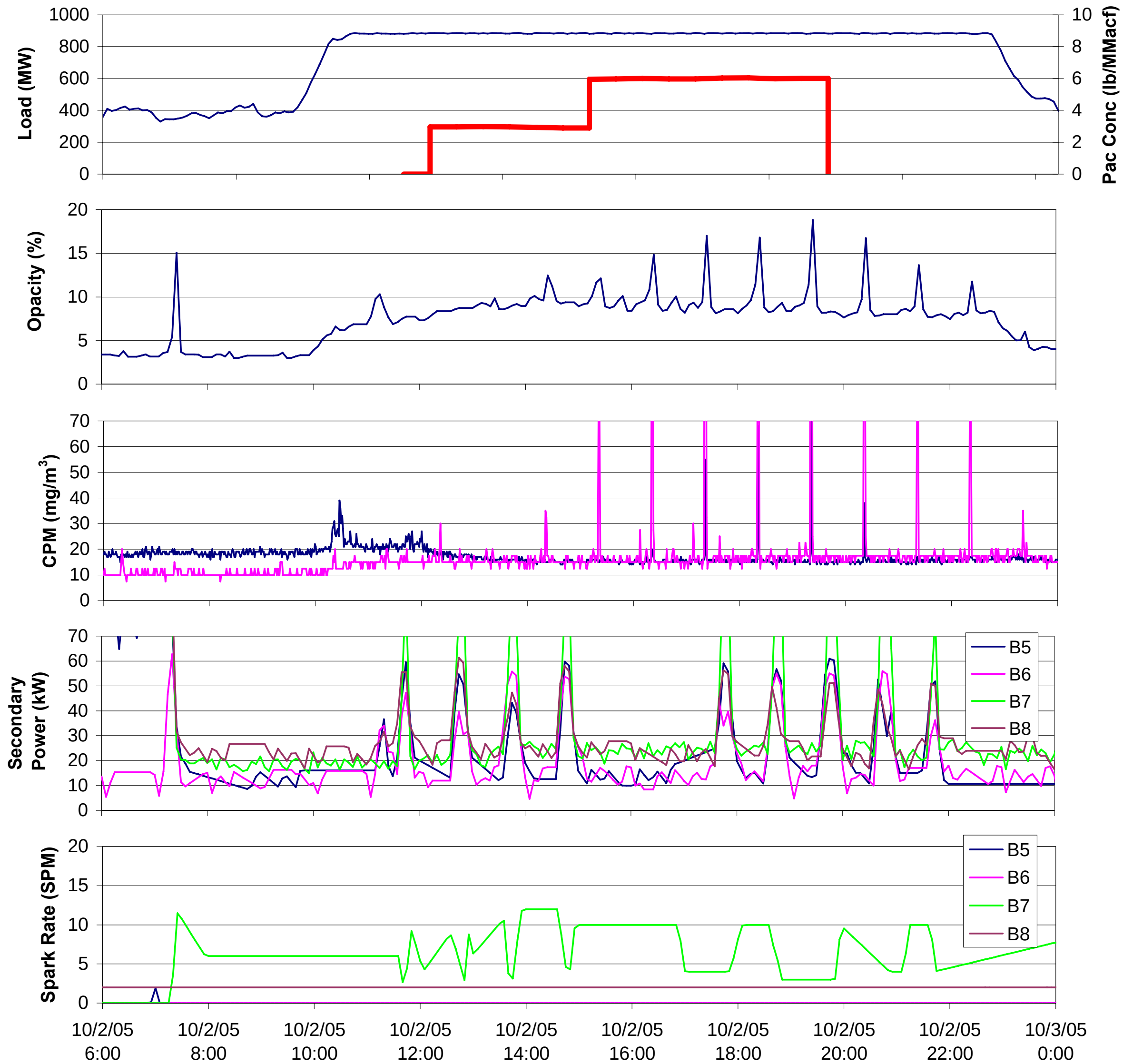


Figure 64. Operating trends during DARCO® E11 injection upstream of field 7.

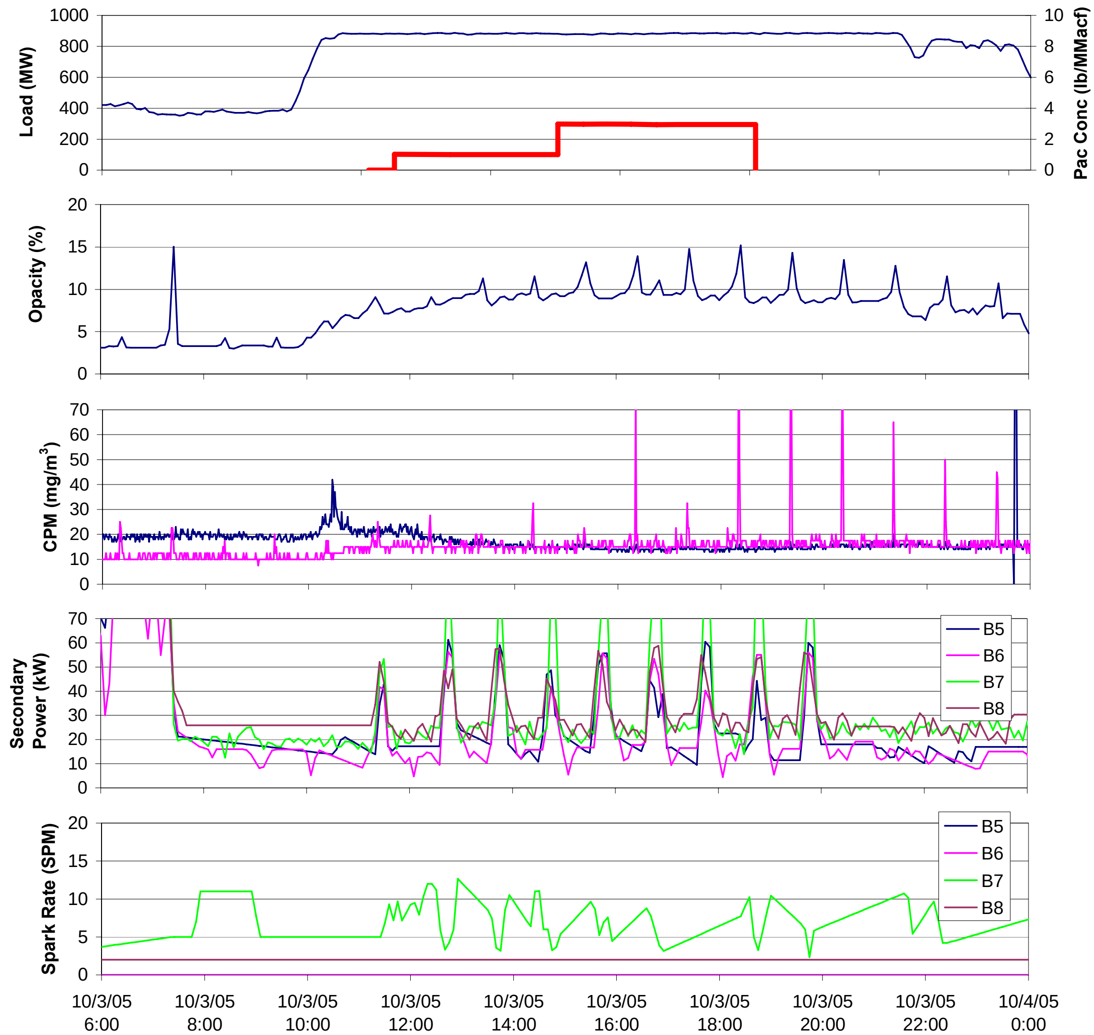


Figure 65. Operating trends during DARCO® Hg injection upstream of field 7.

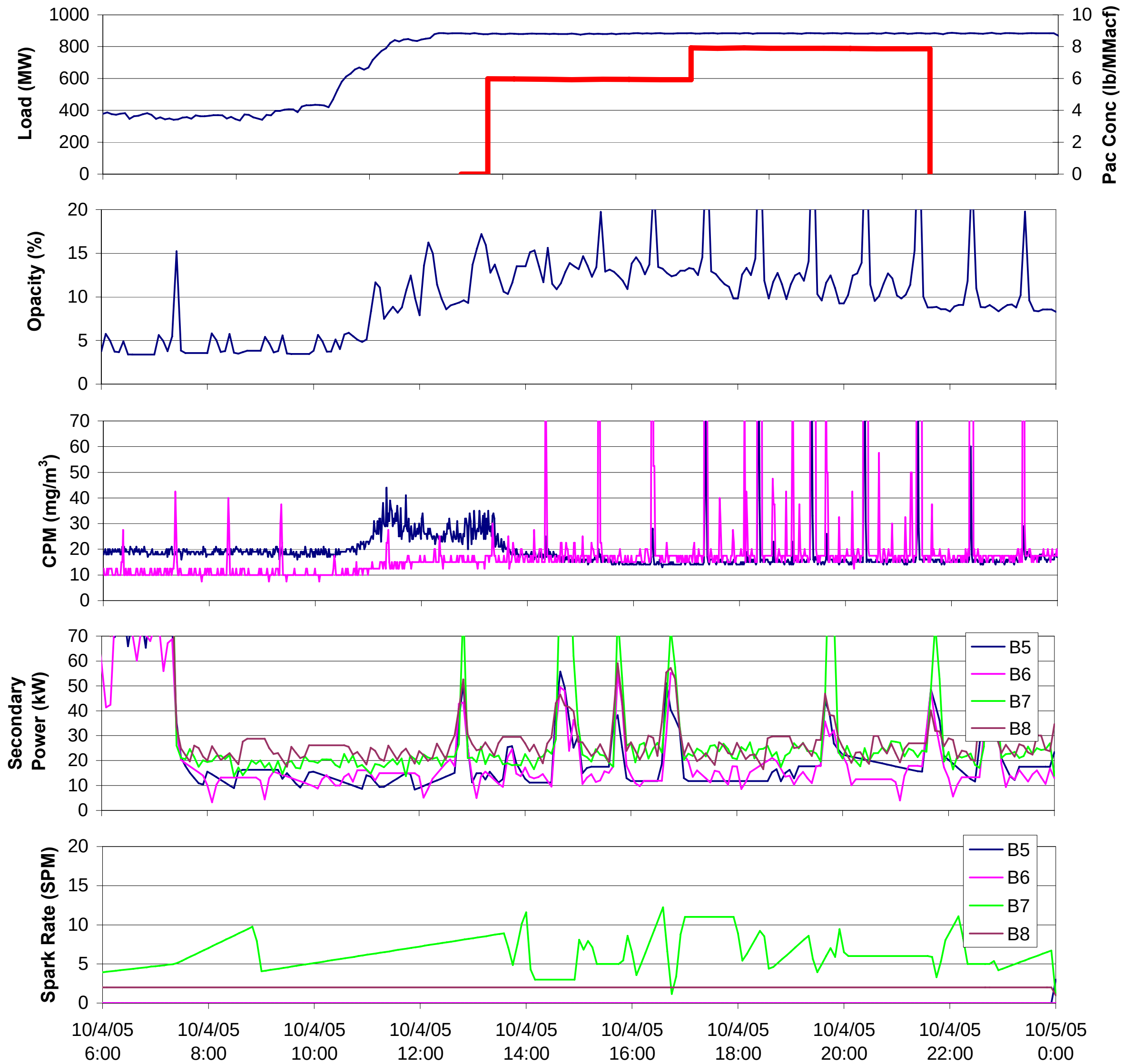


Figure 66. Operating trends during DARCO® Hg injection upstream of field 7.

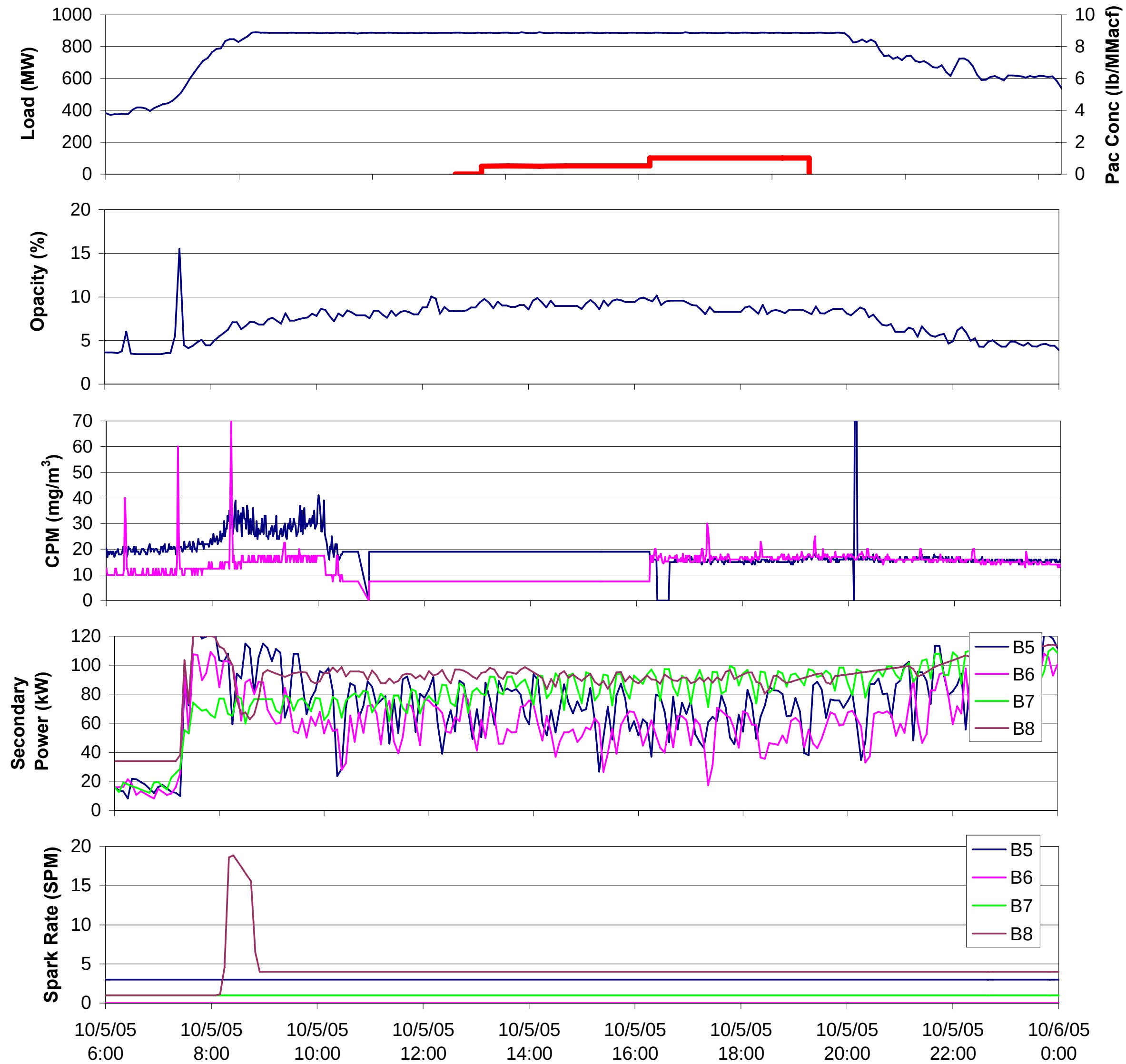


Figure 67. Operating trends during DARCO® Hg-LH injection upstream of field 7.

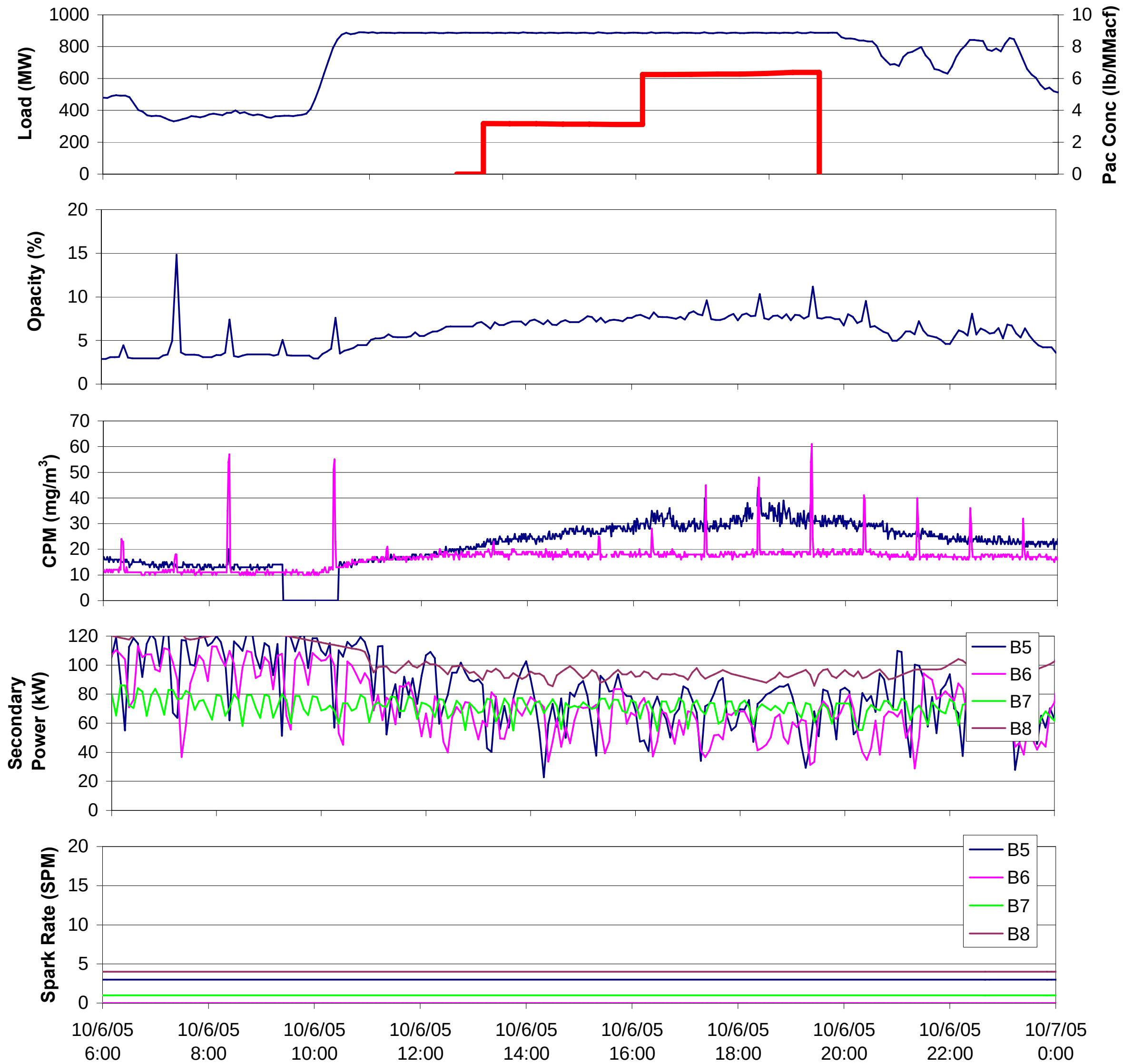


Figure 68. Operating trends during DARCO® Hg-LH injection upstream of field 7.

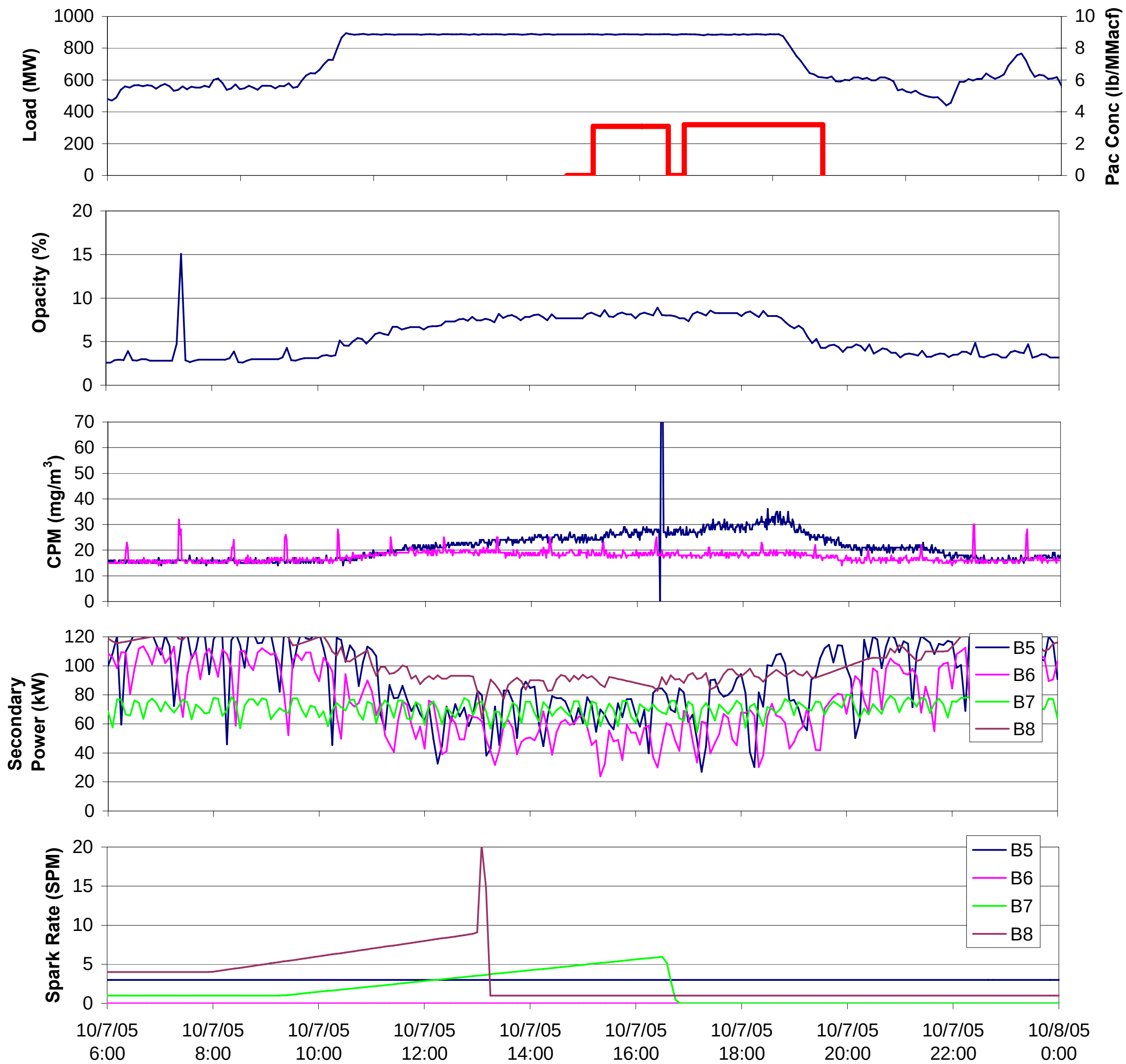


Figure 69. Operating trends during DARCO® Hg-LH injection upstream of fields 5 (first period) and 7 (second period).

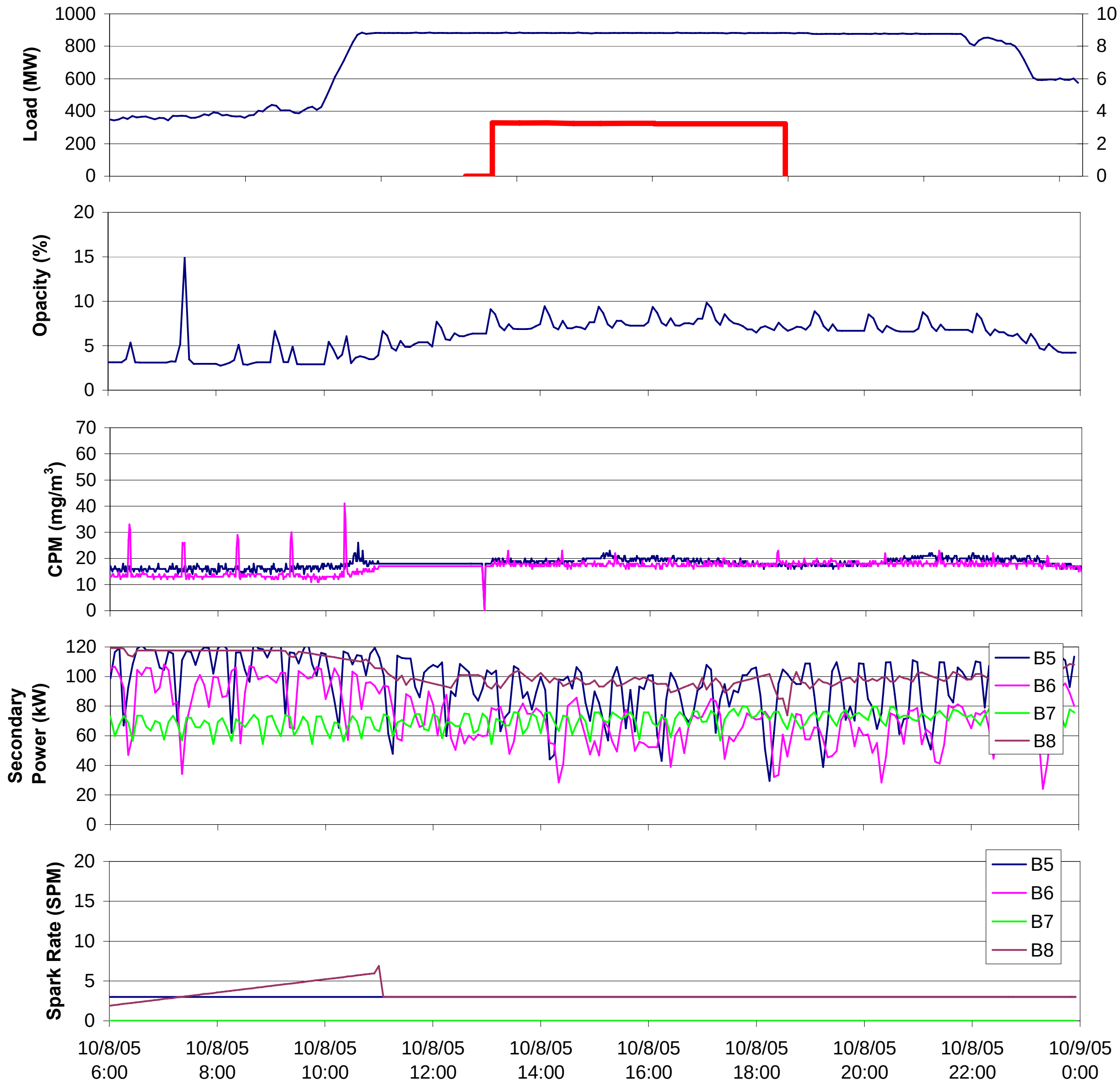


Figure 70. Operating trends during DARCO® Hg-LH injection upstream of fields 5 and 7.

Based on the August trend charts, DARCO® Hg-LH appeared to have slightly less impact on ESP operation than DARCO® Hg or the two derivative DARCO® Hg materials, E-10 and E-11 (Figure 57 through Figure 60). To verify the observed trends at Independence, a two-day supplemental test sequence was carried out in early September 2005 (Figure 61 and Figure 62). During the supplemental testing, the order of testing was reversed from the August test order, with DARCO® Hg-LH being injected in the middle of ESP B-box on September 8, and DARCO® Hg on September 9, 2005. No changes were made in the ESP Power Optimization System. The data suggest that the POS system was not optimized for PAC injection. During injection, the power levels in the T/R sets would often spike up, followed by a period when the power levels returned to a fairly low level. If a rap occurred during the period with low power, there was often a spike in the CPM and opacity measurements. Whisker plots of the opacity results are summarized in Figure 71.

Figure 71 indicates that higher concentrations of DARCO® Hg are associated with increased opacity values when the POS system is operating, especially when the sorbent is injected in the rear injection location (i.e., between F5 and F7). Table 19 shows the averaged (6-minute) stack opacity percentages during 2005 Parametric tests. With the exception of DARCO® Hg, the values are comparable to those during Baseline testing under similar conditions (i.e., high boiler load and rear electrical field B-F7 either non-operational or operational). These findings are not unexpected as only 1/8 of the flue gas stream was treated with PAC mid-ESP which may have been small enough to result in undetectable changes at the stack level. Data from the S-CEM analyzers placed at the test side and control side outlet ducts of ESP B-box can be examined to better evaluate the impact of sorbent injection on particulate emissions exiting the ESP.

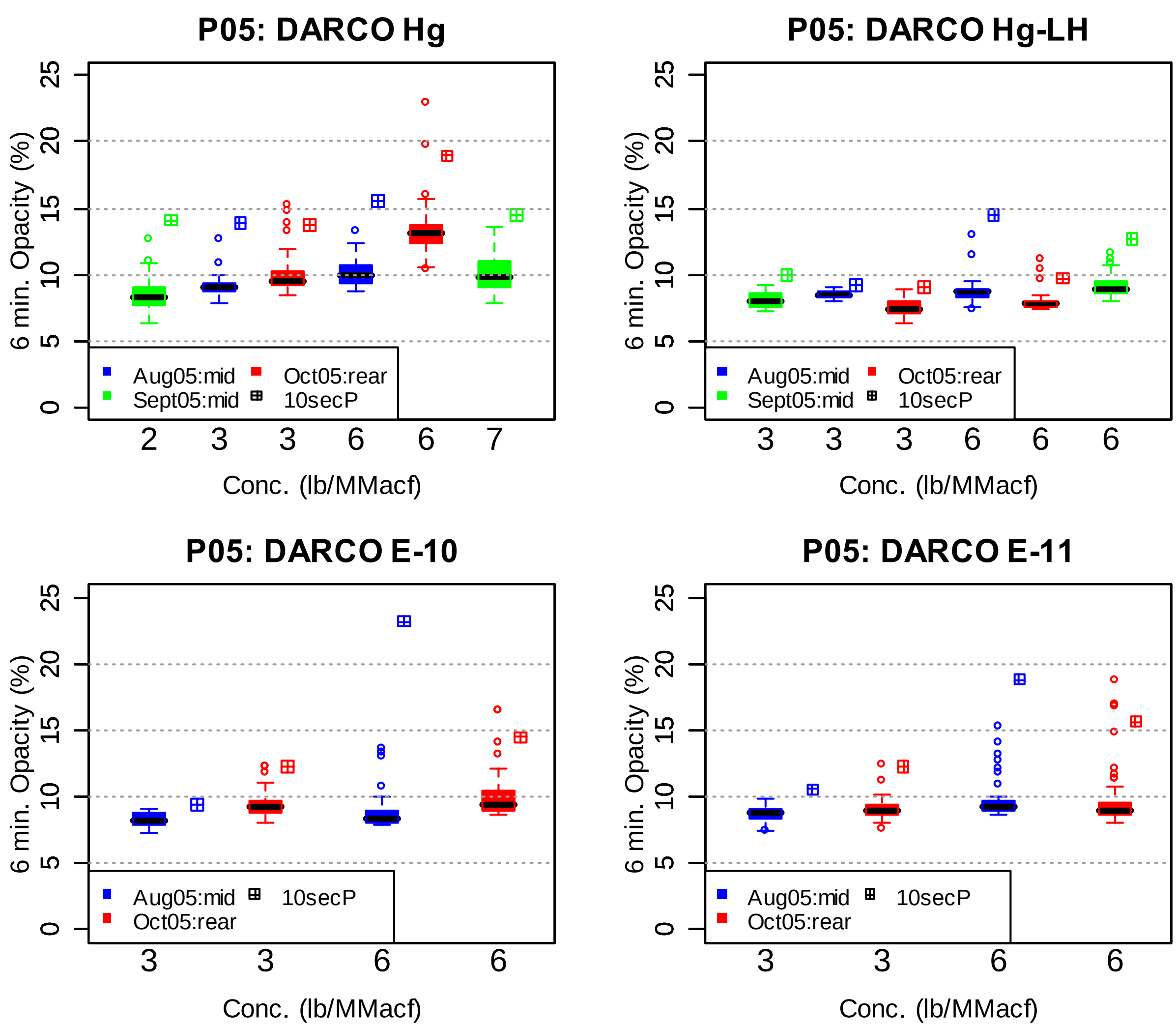


Figure 71. Box whisker plots of (6-minute) stack opacity during 2005 Parametric testing. One-eighth of flue gas stream was treated when PAC was injected either in the mid(dle) or rear of the test side of ESP-B-box during high (> 750 MW) boiler load.

During the October 2005 test sequence, unusually high particulate and opacity spiking was observed during the injection of DARCO® Hg and its derivatives, E-10 and E-11, on October 1–4 while the POS was in operation. The POS was disabled for the remaining PAC injection tests (October 5–8) and the power levels on fields 5 and 7 were increased. This change in ESP operation minimized but did not completely eliminate the spikes in the CPM and Unit 2 opacity measurements during PAC injection (DARCO® Hg-LH).

Table 19. Average (6-minute) stack opacity (%) during 2005 Parametric testing. One-eighth of flue gas stream was treated when PAC was injected either in the mid(dle) or rear of the test side of ESP-B-box during high (> 750 MW) boiler load.

	August 2005: Mid Injection			September 2005: Rear Injection		
DARCO®	3 lb/MMacf	6 lb/MMacf	Average	3 lb/MMacf	6 lb/MMacf	Average
Hg	9.1 ± 0.7	10 ± 1.2	9.6 ± 1.1	10 ± 1.5	13 ± 2.2	11.6 ± 2.5
Hg-LH	8.5 ± 0.2	8.7 ± 1.0	8.5 ± 0.7	7.5 ± 0.6	8 ± 0.8	8.3 ± 0.7
E-10	8.2 ± 0.5	9.2 ± 3.1	8.8 ± 2.3	9.5 ± 1.2	10 ± 1.7	9.8 ± 1.5
E-11	8.7 ± 0.6	9.9 ± 1.6	9.1 ± 1.2	9.1 ± 0.9	9.7 ± 2.3	9.5 ± 1.8

Table 20 gives the average CPM values at the ESP B-box outlet ducts on the test and control sides during October 2005 Parametric tests. When DARCO® Hg-LH was injected at a concentration of 3 lb/MMacf, the CPM values were slightly higher than when the other sorbents were injected and September 2005 baseline CPM values during high boiler load conditions. However, the average CPM value remained unchanged when DARCO® Hg-LH was injected at 6 lb/MMacf while the values increased when each of the other sorbents were injected at the higher concentration. With the exception of DARCO® Hg-LH, the average CPM values on the ESP B-box Control Side during Parametric testing are similar to those observed during September Baseline testing.

Table 20. Average CPM values on test and control sides of ESP B-box during October 2005 Parametric testing. One-eighth of flue gas stream was treated when PAC was injected in the rear of the test side of ESP B-box during high (> 750 MW) boiler load.

	ESP B-box Test Side (mg/m^3)			ESP B-box Control Side (mg/m^3)		
DARCO®	3 lb/MMacf	6 lb/MMacf	Average	3 lb/MMacf	6 lb/MMacf	Average
Hg	17 ± 4.3	20 ± 14.1	24 ± 31.8	14 ± 0.5	17 ± 3.3	17 ± 4.9
Hg-LH	19 ± 4.8	19 ± 3.4	18 ± 3.8	26 ± 3.7	32 ± 4.1	25 ± 8.0
E-10	17 ± 0.8	18 ± 5.1	17 ± 4.0	19 ± 3.3	16 ± 1.7	18 ± 2.9
E-11	16 ± 1.7	21 ± 15.0	19 ± 11.9	16 ± 1.2	16 ± 2.7	16 ± 2.2

Box-whisker plots of the power in ESP B-box third and fourth pairs of electrical fields during 2005 Parametric testing are shown in Figure 72. During the August Parametric tests when F7 was non-operational, power in the remaining rear electrical fields was comparable to levels seen during the August baseline levels at high boiler loads with the exception of DARCO® Hg. When DARCO® Hg was injected at a concentration of 6 lb/MMacf in F5 during August, the power in F5 and F6 was slightly elevated over baseline conditions. During the September Parametric tests when F7 was operational, injections of DARCO® Hg-LH and DARCO® E-10 corresponded to considerably elevated power levels in both pairs of the third and fourth electrical fields.

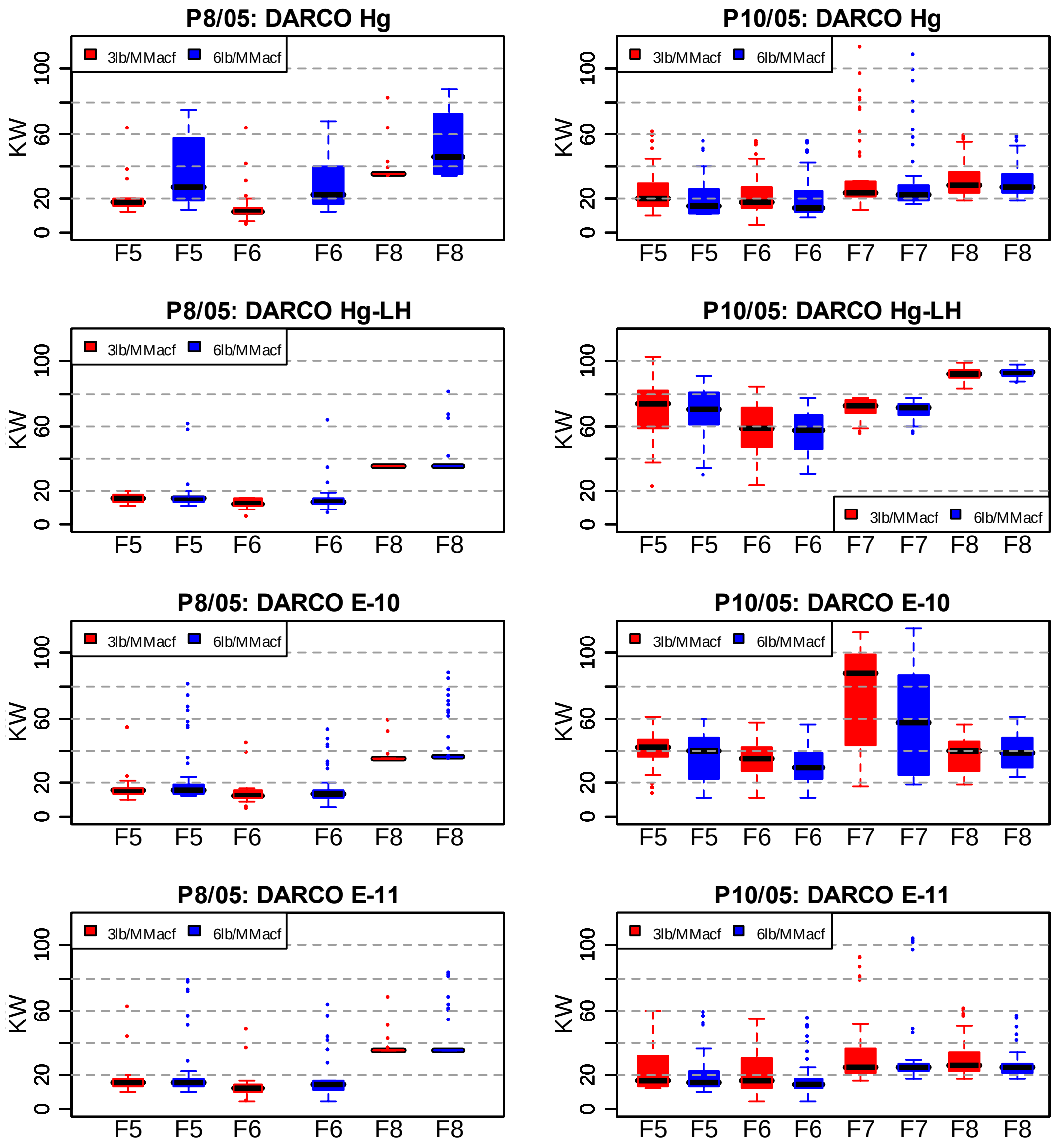


Figure 72. Box-whisker plots of power in ESP B-box rear electrical fields during 2005 Parametric tests. F5 and F6 are the third pair of fields on the test and control sides, respectively; F7 and F8 are the fourth fields on the test and control sides, respectively. One-eighth of flue gas stream was treated when PAC was injected either between F3 and F5 (8/05) or between F5 and F7 (10/05) of the ESP B-box during high (> 750 MW) boiler load.

The average spark rate for the ESP B-box third and fourth pairs of electrical fields during 2005 Parametric testing is shown Figure 73. During injection of DARCO® Hg-LH at a concentration of 6 lb/MMacf, the spark rate in F5 (directly upstream of the injection location) was nearly 4 sparks/min. compared to the August baseline rate of 0. Injection of either 3 or 6 lb/MMacf of both DARCO® E-10 and DARCO® E-11 also corresponded to an increased spark rate in F5. Injection of DARCO® Hg-LH in the rear location (i.e., between F5 and F7) in October corresponded to a spark rate in F5 of 3 sparks/min., which is slightly lower than the September baseline level but higher than the rates observed during injection of the other sorbents. In contrast, the spark rate in F7 during October was considerably elevated over the September baseline level during injection of all sorbents except DARCO® Hg-LH.

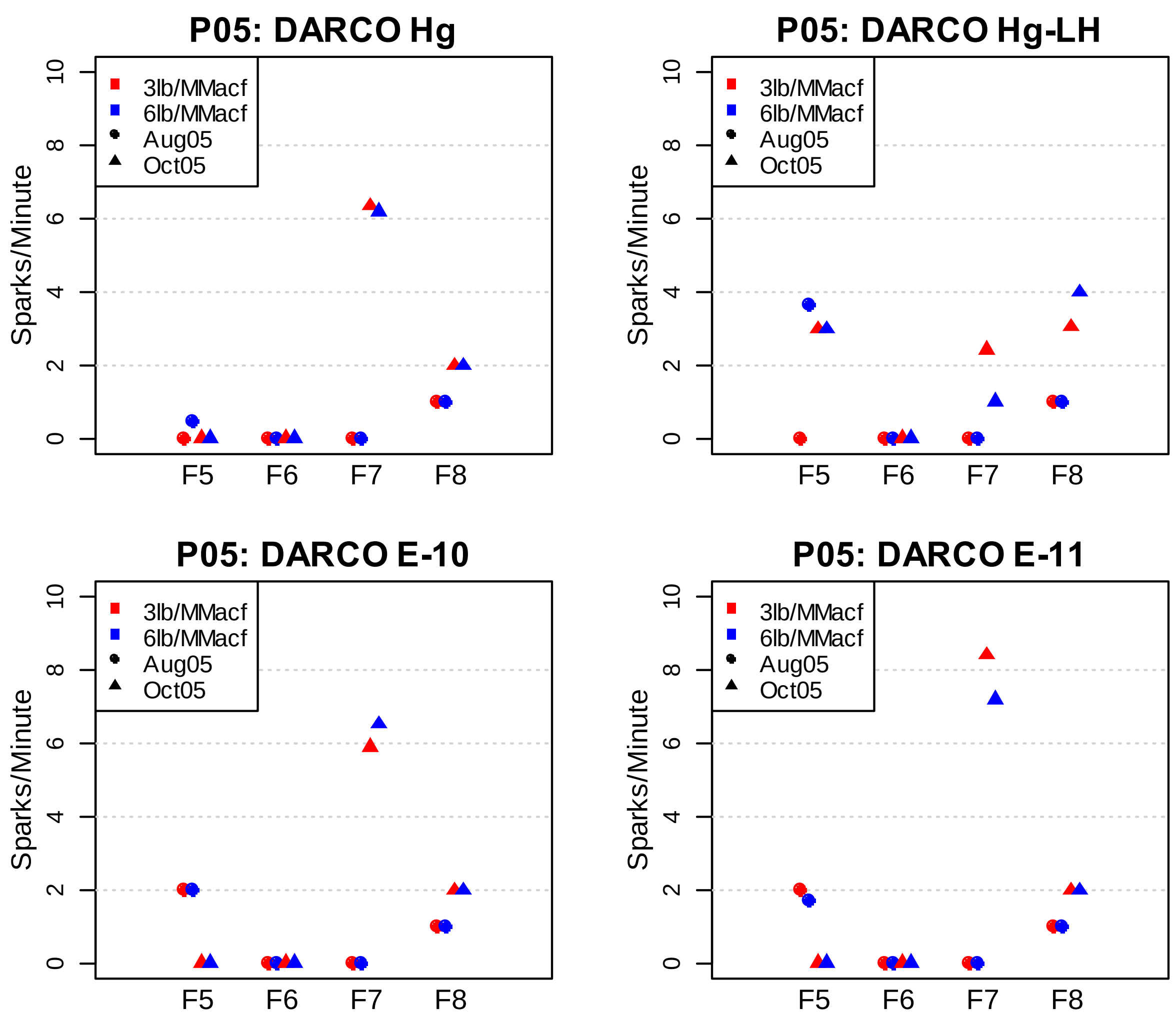


Figure 73. Average spark rates for the ESP B-box last two pairs of electrical fields during 2005 Parametric tests. F5 and F6 are the third pair of fields on the test and control sides, respectively; F7 and F8 are the fourth fields on the test and control sides, respectively. One-eighth of flue gas stream was treated when PAC was injected either directly upstream of F5 (8/05) or directly upstream of F7 (10/05) of the ESP B-box during high (> 750 MW) boiler load.

If the testing protocol for TOXECON II™ were based solely upon an ability to remove mercury, the sorbent of choice for the initial Long-Term test would have been DARCO® Hg. It compared favorably to DARCO® Hg-LH, and as an untreated sorbent, costs approximately half of what the halogenated DARCO® Hg-LH (and other comparable halogenated carbon-based sorbents) cost. At a site utilizing a 100% PRB fuel from the North Antelope mine, a coal source that has been used at other ADA-ES tested sites using PRB fuels, this was an unexpected result and is likely related to the poor sorbent distribution discussed earlier in this report. However, because DARCO® Hg-LH appeared to have favorable particulate control characteristics, it was chosen for the Long-Term testing period.

Long-Term ESP Performance

Based on the 2005 Parametric test results, it was expected that DARCO® Hg-LH would have minimal impact on ESP performance during Long-Term testing. Figure 74 shows trend charts of ESP performance for the entire test period (10/10/05–11/08/05). Recall that the initial Long-Term test sequence was divided into two main phases. During the first phase, sorbent was injected between the last two fields on the test side of ESP B-box. During the second phase, injection was shifted to mid-box (i.e., between the second and third fields). Results from these phases, which are depicted in trend charts, are presented below.

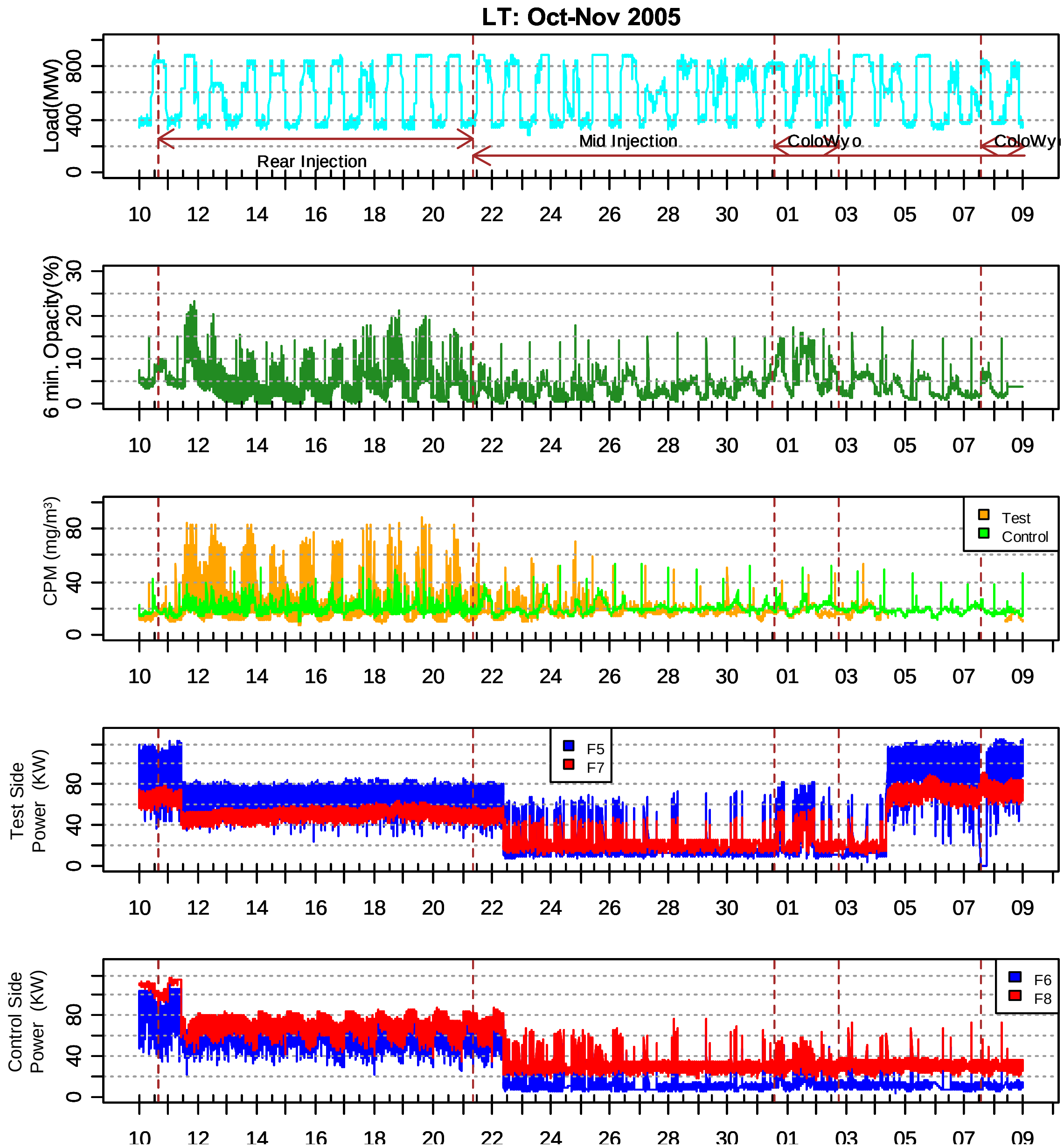


Figure 74. ESP Operation and (6-minute) opacity during October and November 2005 Long-Term testing. Opacity represents stack data. One-eighth of flue gas stream was treated when PAC was injected in the test side of ESP-B.

During the second day of Phase I Long-Term testing, Independence plant personnel expressed concern over the increase in the 6-minute average as well as the peak opacity being reached when using the 10-second instantaneous opacity results. As is evident in the opacity trend chart (Figure 74), opacity levels were exceeding 20% at high boiler loads. The high opacity values were spikes that coincided with rapping which occurred every hour and lasted for 140 seconds. The average 6-minute opacity values were indistinguishable from those observed during September 2005 Baseline testing whether the overall average is considered or the averages at high and low boiler loads (see Figure 75 and Table 21). In an attempt to decrease the opacity spike amplitude, the CE rapper duration for field B-F7, the ESP B test side outlet collection plate, was decreased from 140 seconds to 70 seconds. As can be seen in Figure 76, the 6-minute average opacity spikes dropped from above 15% during the field B-7 rap to below 10% after the shift to a shorter duration cycle. In general 6-minute average opacity also decreased (see Figure 75 and Table 21). The rap duration change lowered not only the 6-minute average opacity, but also the peak opacity spikes as measured by the 10-second instantaneous opacity. However, this may be an aberration introduced by the data collection algorithm for the 10-second opacity measurement. When the continuously measured peak opacity was viewed on the data screens in a continuous graphical format, the spike height appeared to remain the same whether the rap cycle lasted 140 or 70 seconds. During the last few days of October testing when the CPM and opacity monitor recorded few spikes resulting from Hg-LH injection, B-F5 power was typically between 60 and 80 kW. B-F7 power was typically near 100 kW. During the initial Long-Term testing period, the B-F7 power was less than 80 kW. Before the CPM and opacity spikes began, power levels on B-F5 and B-F7 were both decreased.

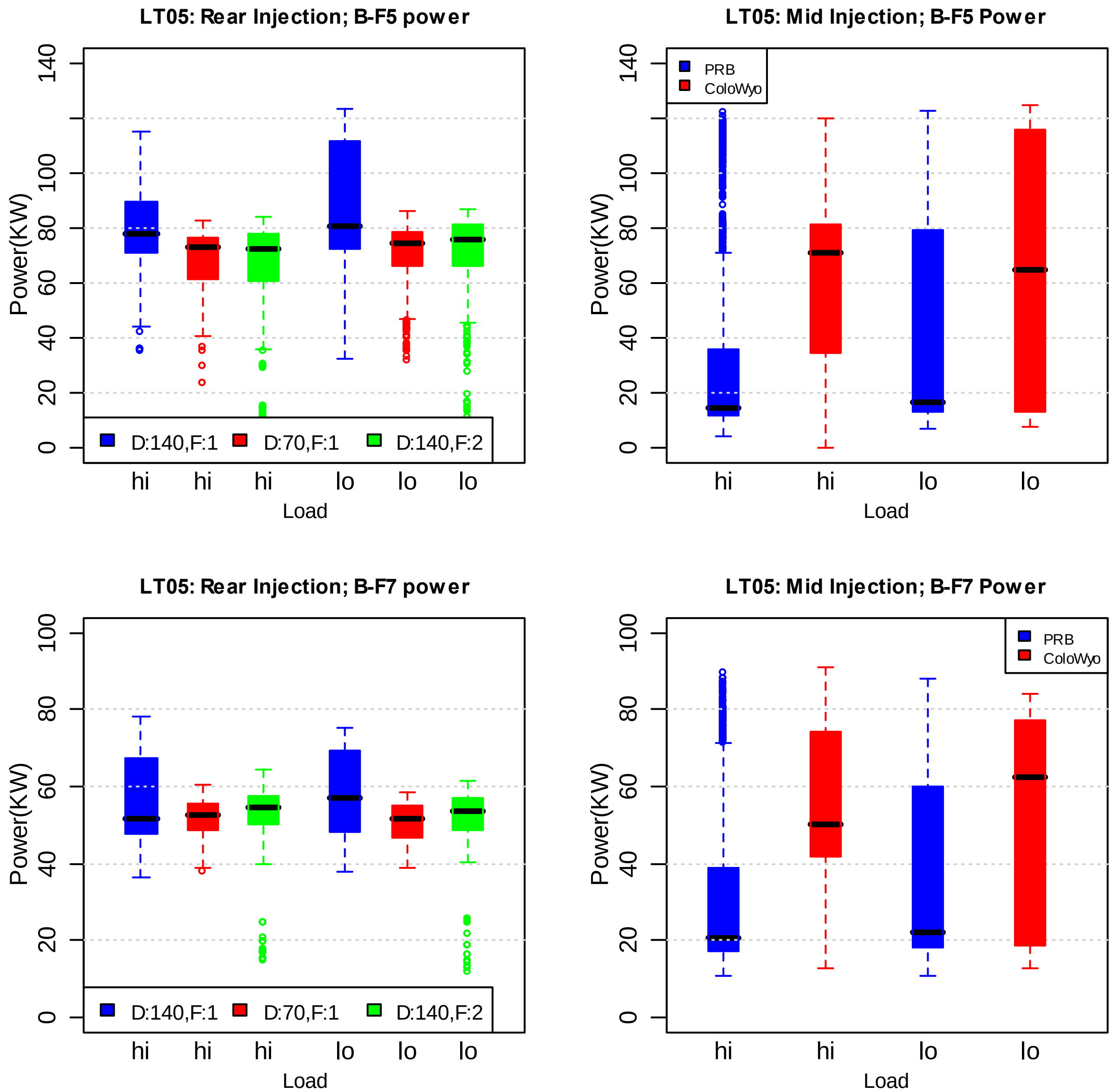


Figure 75. Box whisker plots of power in the two rear electrical fields on the test side of ESP B-box during 2005 Long-Term testing. (See caption for Figure 78 for explanation of sorbent injection conditions.)

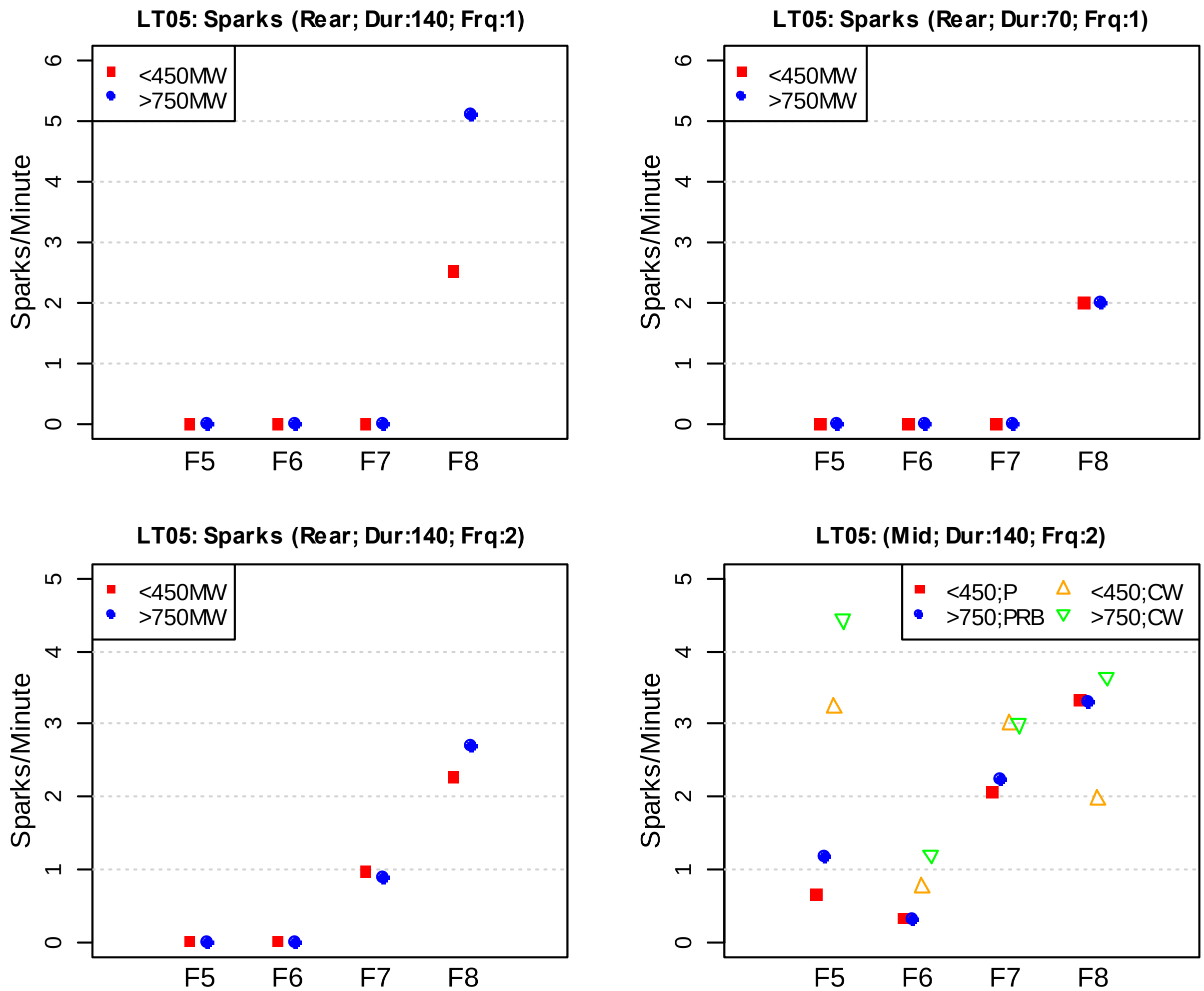


Figure 76. Average spark rate in ESP B-box electrical fields during 2005 Long-Term testing. F5 and F6 are the third fields on the test and control sides, respectively; F7 and F8 are the last fields on the test and control sides, respectively. Plot contrasts overall spark rates with those when boiler load is at high loads (> 750 MW) and low load (< 450 MW). (See caption for Figure 78 for description of ACI conditions.)

Recall that on October 16, the injection concentration was increased from nominally 4 lb/MMacf to nominally 5 lb/MMacf in an effort to improve mercury removal across the ESP B-box. No discernable changes in opacity levels were detected with the increase in sorbent concentration. On October 17, the rapping cycle for B-F7 was extended from once per hour to every other hour. To prevent an unusual build up of material on the plates, the same amount of rapping per 24-hour period was achieved by increasing the rap duration to 140 seconds. The opacity trend chart in Figure 77 clearly depicts the shift in rapping frequency. Also evident is the increase in opacity spike amplitude at high load most likely due to the increase in rap duration to 140 seconds. However, the 6-minute opacity levels in general did not show such a pronounced increase (Figure 78 and Table 21).

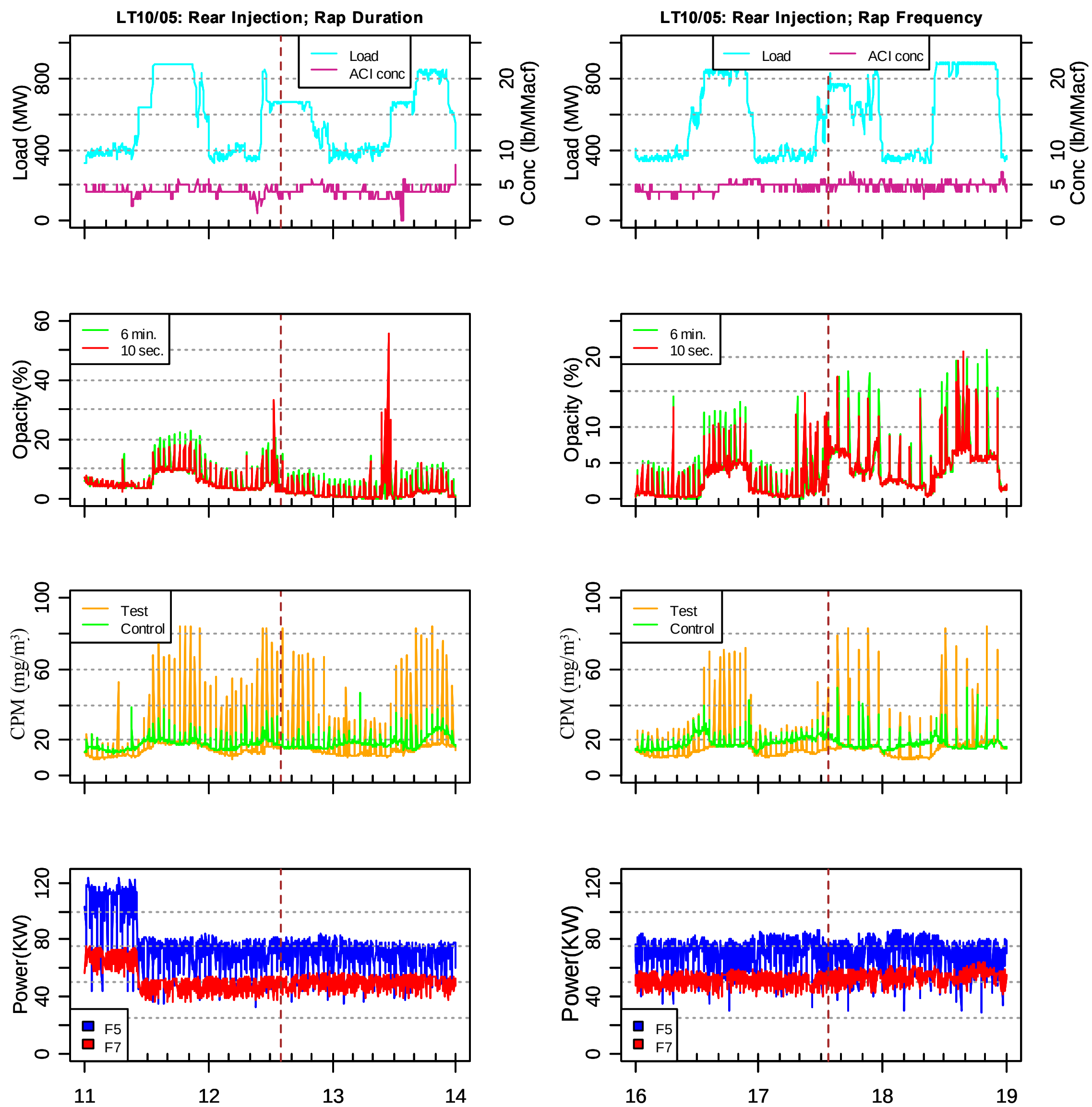


Figure 77. ESP Operation and (6-minute) opacity during shifts in CE rapper B-F7 rap duration and frequency. The vertical dashed line in the left charts indicates the shift in rap duration from 140 seconds to 70 second once per hour. The vertical dashed line in the right charts indicates the shift in rap duration back to 140 seconds accompanied by a decrease in frequency to every two hours.

The CPM trend charts in Figure 77 also show spikes that coincide with the rapping cycle. The amplitude of the spikes is well above 2005 Baseline levels. In general, Phase I CPM levels were slightly elevated over September 2005 Baseline levels for similar load conditions regardless of rapping duration or frequency (see Figure 79 and Table 22).

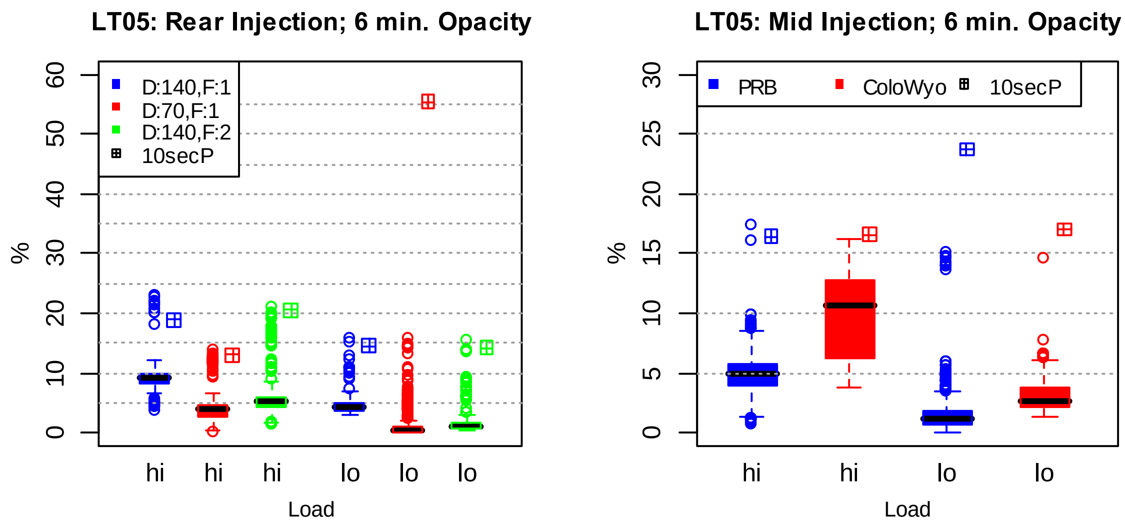


Figure 78. Box whisker plots of (6-minute) stack opacity during 2005 Long-Term testing. One-eighth of flue gas stream was treated when PAC was injected either in the mid(dle) or rear of the test side of ESP B-box during hi (> 750 MW) and lo (< 450 MW) boiler loads. Rear injection included three different rapper protocols for field B-F7: (1) duration of 140 seconds once per hour (D:140,F:1), (2) duration of 70 seconds once per hour (D:70,F:1), and (3) duration of 140 seconds once every 2 hours. Also shown is the 10-second peak opacity value for the same conditions. During the mid injection phase, coal from the ColoWyo mine was burned in place of the typical PRB coal during two short periods.

Table 21. Average (6-minute) stack opacity during 2005 Long-Term testing. (See caption for Figure 78 for description of ACI conditions.)

	Average 6-Minute Opacity (%)		
ACI Conditions	< 450 MW	> 750 MW	Overall
Rear Injection Rap Duration: 140 seconds Frequency: 1 hour	4.6 ± 1.7	9.5 ± 3	6.4 ± 3.4
Rear Injection Rap Duration: 70 seconds Frequency: 1 hour	1.1 ± 2.2	4.3 ± 2.5	2.1 ± 2.6
Rear Injection Rap Duration: 140 seconds Frequency: 2 hours	1.6 ± 1.7	5.8 ± 3	3.6 ± 3.1
Mid Injection	1.4 ± 1.3	4.9 ± 1.4	3 ± 2.0
Mid Injection (ColoWyo)	3.1 ± 1.5	9.5 ± 3.7	6 ± 3.8

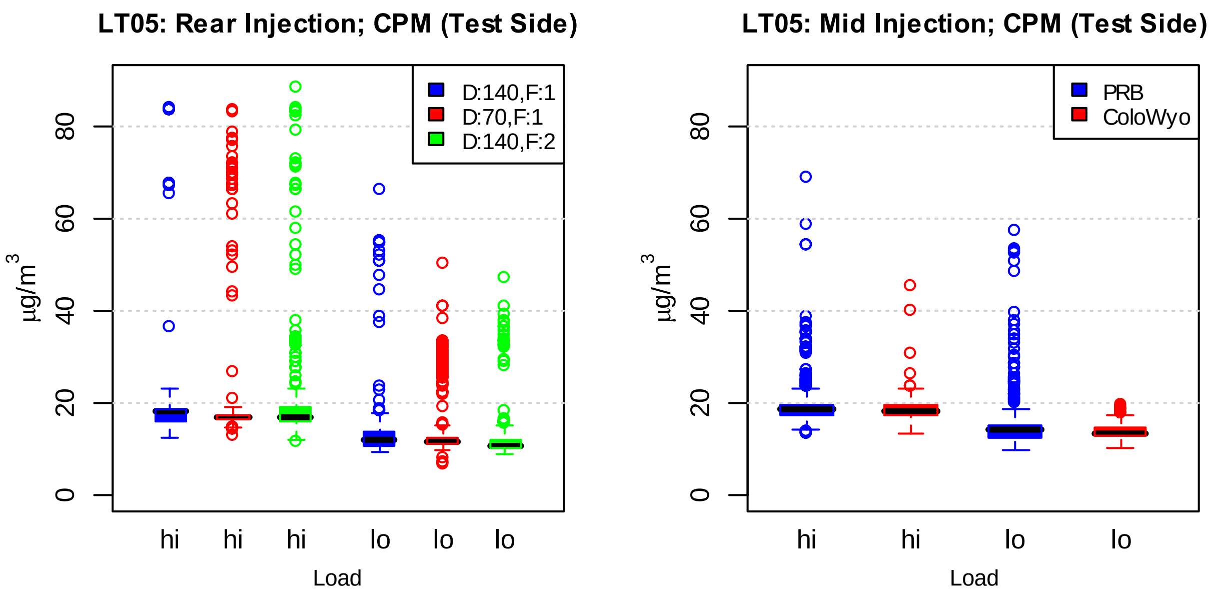


Figure 79. Box whisker plots of CPM values at the test and control outlet ducts of ESP B-box during 2005 Long-Term testing. (See caption for Figure 78 for explanation of sorbent injection conditions.)

Table 22. Average CPM values at the test outlet duct of ESP B-box during 2005 Long-Term testing. (See caption for Figure 78 for explanation of sorbent injection conditions.)

	ESP B-box (test side) Average CPM (mg/m^3)		
ACI Conditions	< 450 MW	> 750 MW	Overall
Rear Injection Rap Duration: 140 seconds Frequency: 1 hour	14 ± 8.5	21 ± 13	17 ± 12
Rear Injection Rap Duration: 70 seconds Frequency: 1 hour	13 ± 5.3	21 ± 15	17 ± 11
Rear Injection Rap Duration: 140 seconds Frequency: 2 hours	12 ± 4.9	21 ± 12	16 ± 10
Mid Injection	15 ± 4.1	19 ± 3.4	17 ± 4.1
Mid Injection (ColoWyo)	14 ± 1.8	19 ± 3.0	16 ± 3.3

In general, power in the ESP B-box rear electrical fields was higher during Phase I of Long-Term testing than during 2005 Baseline testing. Moreover, from the morning of the second day of testing through the end of Phase I, power levels remained within approximately the same range regardless of load in B-F5 and (a slightly lower range for) B-F7 (Figure 74 and Figure 75).

The average spark rate during Long-Term Phase I testing for the last two pairs of electrical fields in the ESP B-box is shown in Figure 76. In general, spark rates are the same or lower than those during 2005 Baseline and Parametric testing. An exception is the spark rate in B-F8, which tends to be higher than was observed during baseline. Also, the spark rate in B-F7 when rapping duration was 140 seconds every two hours was slightly higher than baseline but lower than the rate observed during the Parametric tests.

Trend charts indicating the shift between Phase I (rear-box injection) and Phase II (mid-box injection). Long-Term tests are shown in Figure 80. A decrease in opacity was expected when moving the injection location from rear to mid-box as the effective SCA available for particle capture doubled. (A collection field at Independence was rated at an effective SCA = 135 ft^2/kacfm.) Figure 74 shows more clearly the difference between the two phases in ESP performance. For example, a decrease in both the 6 min. opacity spike amplitude and CPM spike amplitude is evident. In general, 6-minute opacity remained below 15% during Phase II. From the plant’s viewpoint this decrease was a significant change as it allowed a margin of error to prevent a reportable opacity violation.

Figure 78 and Table 21 summarize the 6-minute stack opacity values and Figure 79 and Table 22 summarizes the CPM values for Phase II. Although opacity values decrease during Phase II, CPM values do not show much change and remain slightly elevated relative to Baseline conditions. In contrast, EPA Method 17 tests conducted during Phase II show elevated PM levels at the inlet to ESP B-box but decreased levels at the outlet to ESP B-box relative to those conducted during 2005 Baseline tests (see Table 23 and Appendix D for the full report). For reference, Figure 81 shows trend charts for the days when the M17 tests were conducted.

On October 24, the injection location was shifted from mid-box to rear-box and back to mid-box over the course of several hours (Figure 80). The system response to the change is most apparent during the second shift when there is a pronounced spike in both opacity (> 15%) and CPM levels which may be related to PAC build up on the rear collection plates. During Parametric testing it was noted that the effects of PAC build up on the ESP collection plates can take up to 18 hours to dissipate.

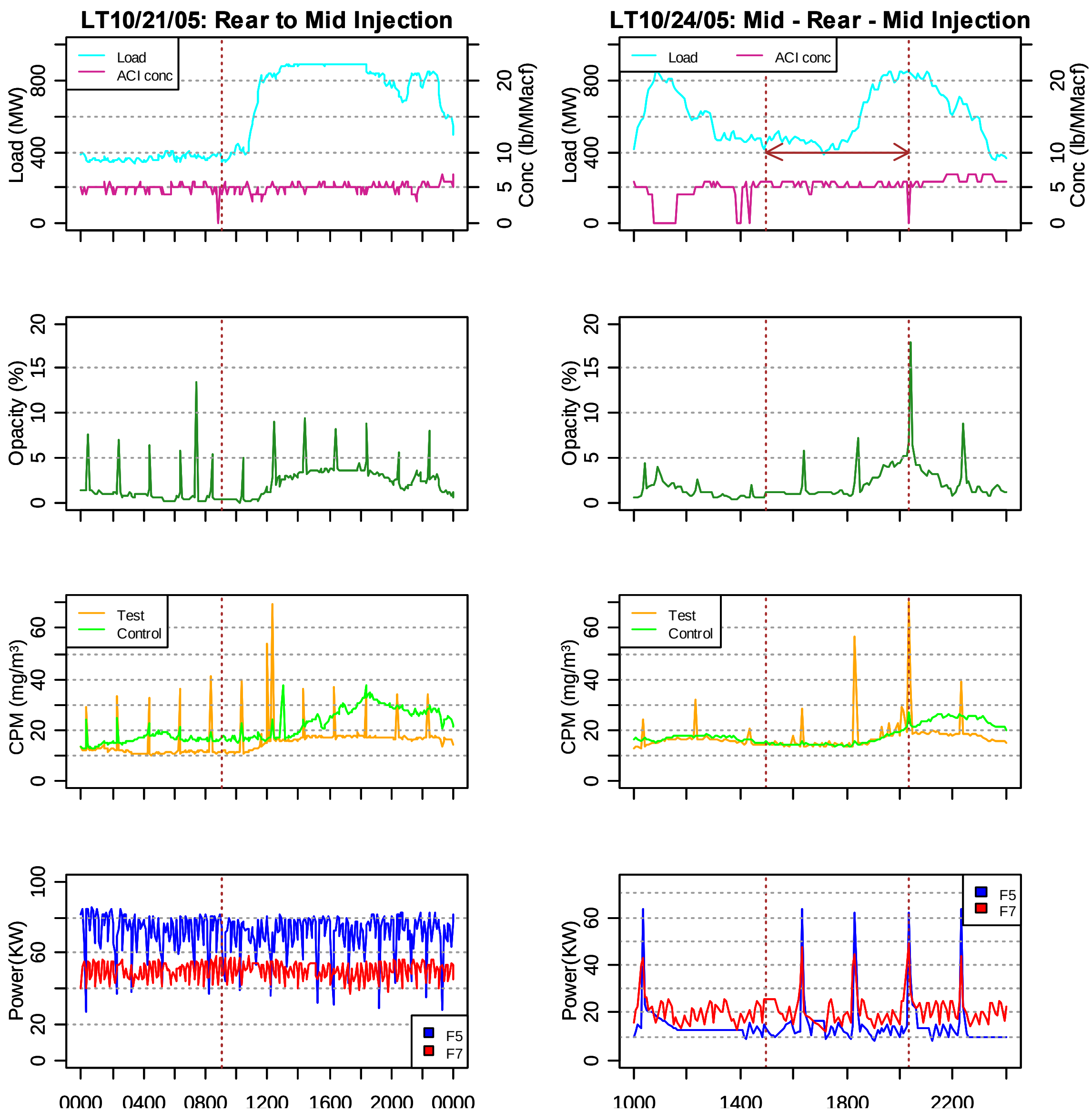


Figure 80. ESP operation and (6-minute) stack opacity during shifts in PAC injection location. The vertical dashed line in the left charts indicates the shift from injecting between ESP B-box F5 and F7 (rear-box) to between F3 and F5 (mid-box). The first vertical dashed line in the right charts indicates shift from mid-box to rear-box injection and the second line indicates the shift back to mid-box injection.

Table 23. Method 17 results for Unit 2 during 2005 Long-Term testing.

Run #	ESP B Inlet Duct gr/dscf	ESP B Outlet Duct gr/dscf	Decrease %
1 (10/25/05)	2.014	0.004	99.8
2 (10/25/05)	2.528	0.006	99.8
3 (10/26/05)	2.071	0.004	99.8
Average	2.204	0.005	99.8

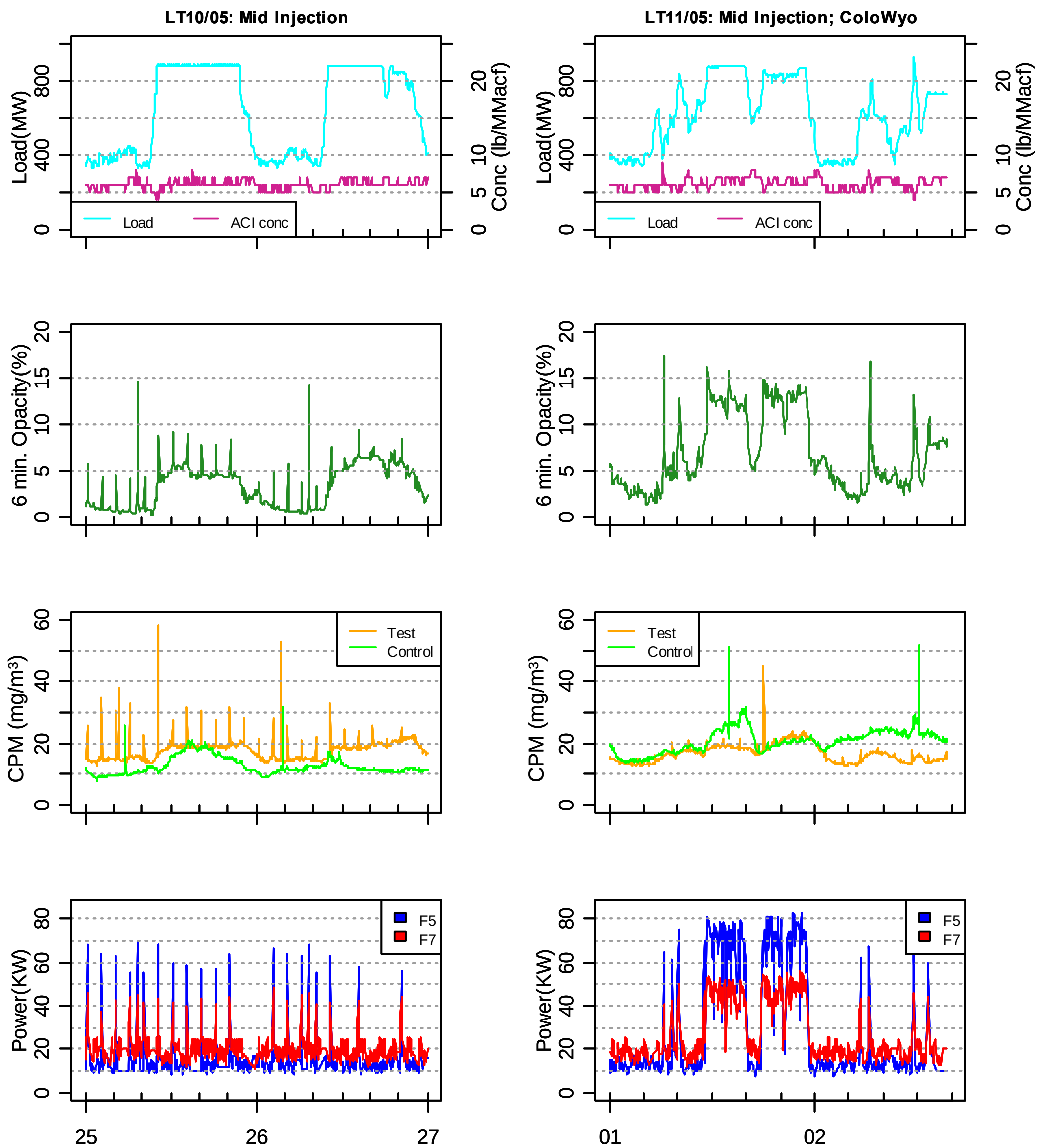


Figure 81. ESP Operation and (6-minute) stack opacity during days when M17 (October 25–26, 2005) and Ontario Hydro (both October 25–26 and November 1–2, 2005) tests were conducted while sorbent was injected into 1/8 of the flue gas stream in ESP B-box between fields F3 and F5 (mid-box).

As is evident in Figure 74 and Figure 75, power in the ESP B-box rear fields on the test side (F5 and F7) was much more variable during Phase II than Phase I. Moreover, spark rates tended to be higher in all rear fields during Phase II than Phase I. However, spark rates were similar to those observed during 2005 Parametric testing, including higher rates in F7 and F8 compared to 2005 Baseline.

On October 30, the sorbent injection concentration was temporarily increased from nominally 5 lb/MMacf to nominally 8 lb/MMacf (Figure 82). There was no noticeable increase in emissions rate for particulate as measured by the CPM data or the plant opacity meters.

On November 4, the rear fields of the test side of ESP B were removed from the controls of the Precipitator Optimization System (POS) for several hours. The POS is designed to react to changes in the plant opacity by raising and lowering the power output of the T/R sets. In Figure 82, the increase in field B-7 power can be clearly observed during the spikes in opacity in the morning of November 4.

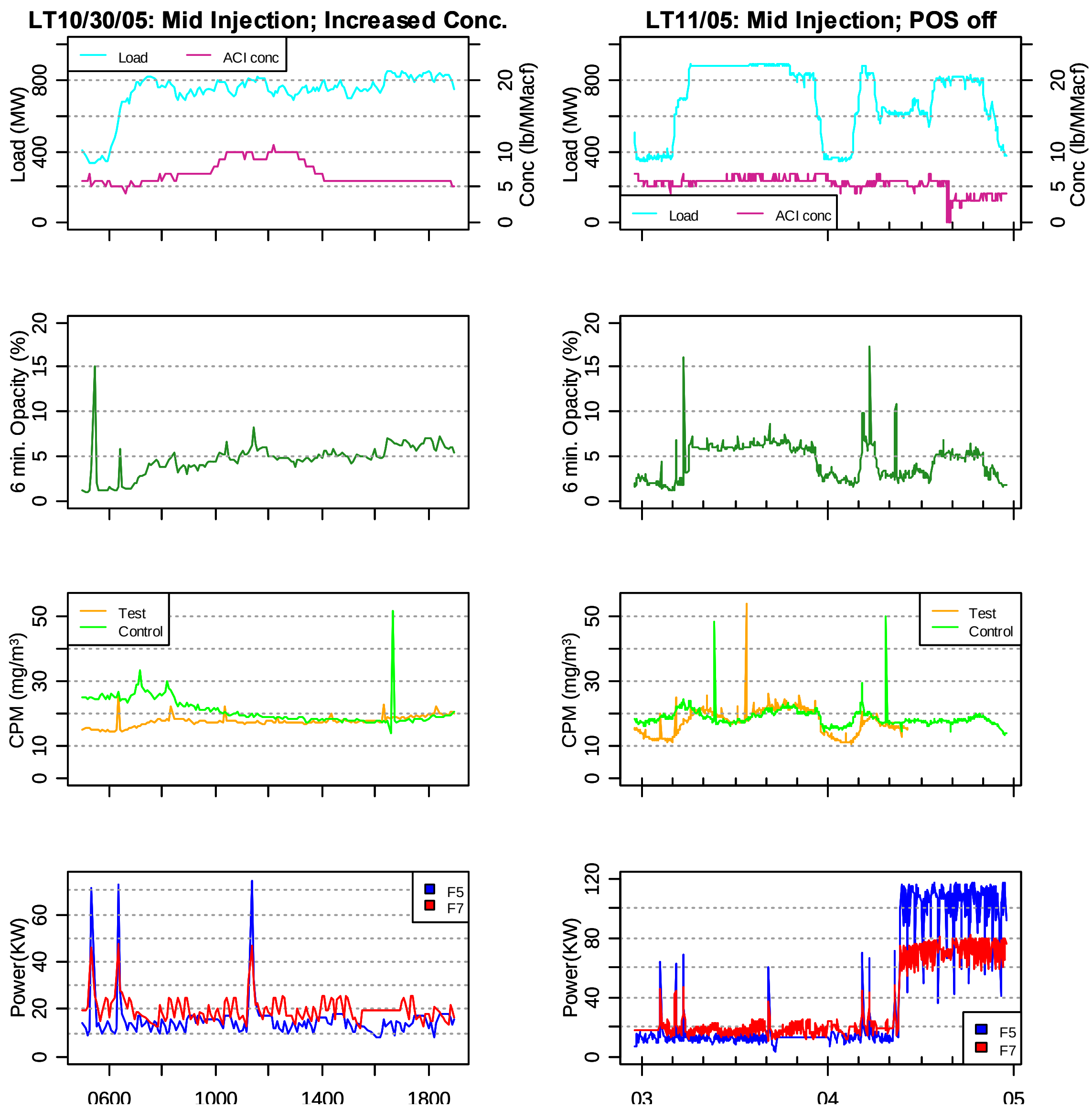


Figure 82. ESP Operation and (6-minute) stack opacity during a temporary increase in sorbent concentration (left charts) and while rear fields of the test side of ESP B were temporarily removed from the POS (right charts).

Twice during Phase II of Long-Term testing coal from the ColoWyo mine was burned as fuel. These periods are indicated in Figure 74. For reference, trend charts covering the same period as when Ontario Hydro tests were conducted in early November are given in Figure 81. In general, 6-minute stack opacity was elevated when ColoWyo was burned compared to PRB (Figure 78). Moreover, power in ESP B-F5 and F7 was more variable (Figure 75). However, CPM values at the ESP B-box outlet duct on the test side were comparable to those when PRB was burned (Figure 79 and Table 22).

Redesigned Grid

During evaluation of the redesigned injection grid and delivery system in 2007, particulate emissions measurements using EPA M5/202 were measured at three locations in the Independence gas stream: at the outlet of the west side of the B-West ESP (test-side), the east side of the B-West ESP (control-side) and at the stack (Appendix D5). Two continuous particulate monitors were installed and operated during testing: one across the outlet of the B-West ESP and one across the B-East ESP. The stack opacity monitor was also used to determine whether any excess emissions from testing on 1/32 to 1/16 of the unit resulted in an increase in the stack opacity.

A summary of the stack PM measurements is included in Table 24 along with average opacity and unit load for the sampling period. The stack data suggest that there was an increase in the PM emissions between the Baseline test period (January 29–February 2, 2007) and the stack testing during PAC injection (February 12–13, 2007) (see Table 25). The opacity trend shown in Figure 83 indicated that there was an increase in the stack opacity correlating to an increase in PAC injection into 1/16 of Unit 2 on February 8, 2007. Thus, the measured increase in particulate at the stack may have been caused by PAC injection and not another operational change at the plant. However, when PAC injection was stopped on March 9, there was not a significant corresponding decrease in the opacity, suggesting that there may be more than one contributor to the increase in opacity.

Table 24. Baseline PM measurements – stack.

	Run 1	Run 2	Run 3	Run 4	Run 5	Base Average
Test Date	1/29/07	1/30/07	1/31/07	2/1/07	2/2/07	
Time	0830–1533	0645–1336	0642–1320	0705–1342	0700–1336	
FPM (gr/dscf)	0.0032	0.0032	0.003	0.0031	0.0033	0.0032
CPM (gr/dscf)	0.003	0.0042	0.0035	0.0027	0.0033	0.0033
TPM (gr/dscf)	0.0062	0.0074	0.0065	0.0058	0.0066	0.0065
Load	886	887	890	891	891	
Opacity	6.5	7.0	6.7	7.1	7.5	

Table 25. PAC injection with redesigned grid PM measurements – stack.

	Run 1	Run 2	PAC Average
Test Date	2/12/07	2/13/07	
Time	0724–1405	0810–1446	
FPM (gr/dscf)	0.0041	0.0048	0.0045
CPM (gr/dscf)	0.0028	0.0052	0.0045
TPM (gr/dscf)	0.0069	0.01	0.009
Load	891	891	
Opacity	9.6	10.7	

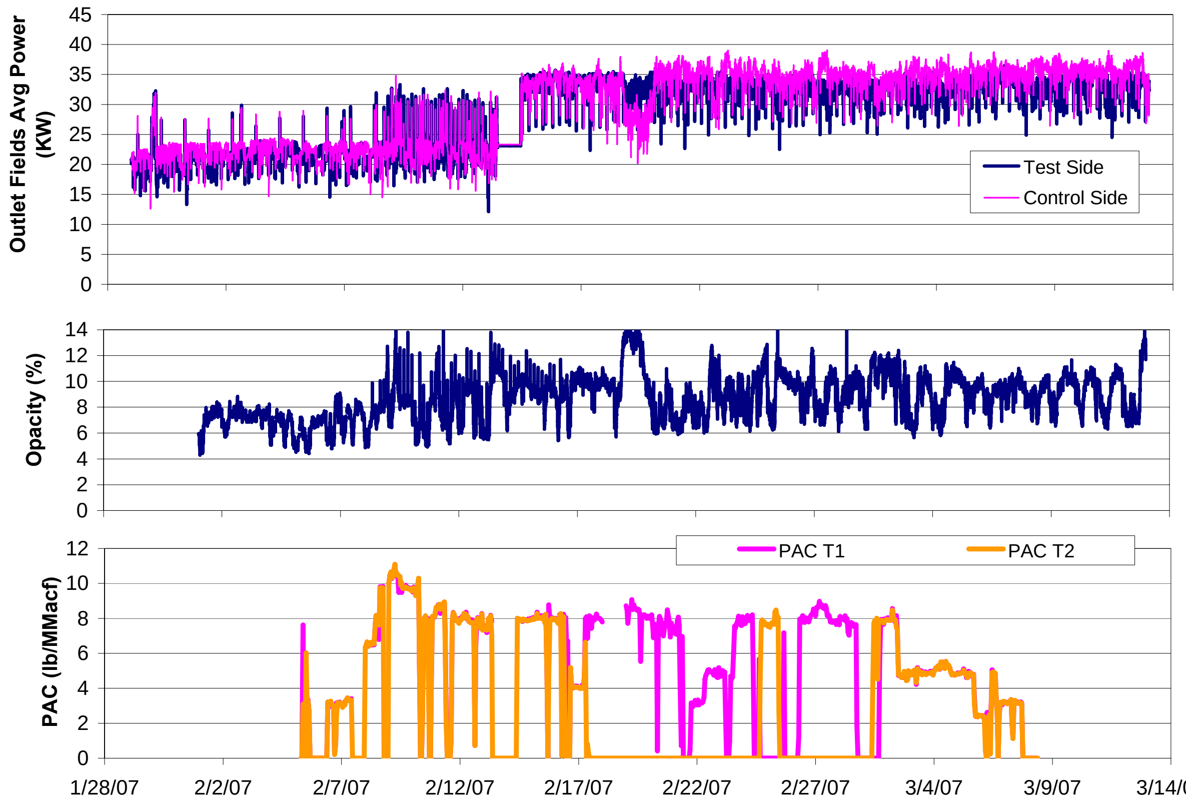


Figure 83. Opacity and ESP power trends with and without PAC injection (redesigned injection grid).

Recall that the CPM monitors were installed across the entire outlet ducts of the B-West ESP and the B-East ESP and that PAC was injected into one-half of the B-West ESP (i.e., 1/16 of the flue gas stream). When the CPM trace from the B-West ESP is compared to the stack opacity, a clear correlation between CPM spikes, caused by fourth field raps, and stack opacity spikes can be seen (Figure 84). On February 16, the rapping frequency was increased from once every four hours to once every one hour. Although this change decreased the amplitude of the rapping spikes, they are still observable at the B-ESP outlet and at the stack. No spikes were observed prior to PAC injection or on the B-East ESP CPM trace.

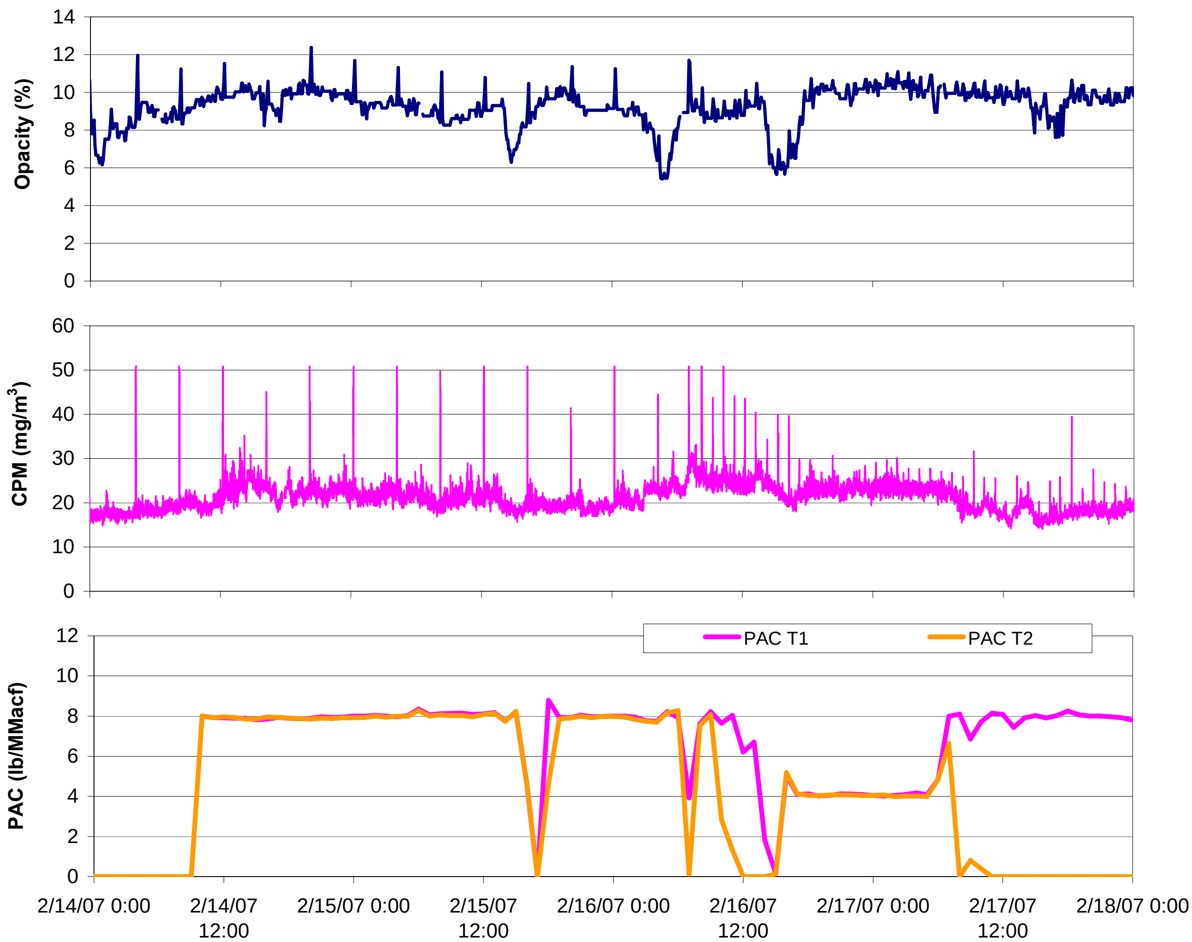


Figure 84. Opacity and ESP power trends with and without PAC injection (redesigned injection grid).

EPA M5/202 measurements were conducted at the outlet of the B-West ESP on February 15–19, 2007. Six-point traverse samples were collected from a single port on both the west half of the B-West ESP outlet and the east half of the B-West ESP outlet (control). Each port was roughly 5 feet from the centerline of the B-West outlet duct. Particulate data are summarized in Table 26, Table 27, and Figure 85. The results indicate that there was no significant difference in the outlet PM emissions at the outlet of the B-West ESP. This outcome is somewhat inconsistent with the data presented in the previous paragraphs. The data also indicate that the filterable PM emissions are significantly higher at the outlet of the ESP than those measured at the stack. The former had an average of 0.0067 gr/dscf and the latter had 0.0032 gr/dscf during Baseline testing compared to 0.0076 gr/dscf and 0.0045 gr/dscf, respectively, during PAC injection.

Hour average CPM data from the B-West and B-East ESP, presented in Figure 86, indicate that the B-East ESP (no PAC injection) was often higher than the B-West ESP (PAC on one-fourth to one-half of box). Although there is no EPA M5 data available from the ESP outlets prior to PAC injection, the CPM data collected before and during PAC injection suggest there was little measurable change in the PM emissions at the ESP outlet due to PAC injection. As was observed during 2005–2006 testing, the B-East CPM appeared to be biased in reporting increased emissions. No bias was noted on the B-West CPM.

Table 26. B-west ESP east (no PAC) outlet PM measurements.

	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Test Date	2/15/07	2/16/07	2/17/07	2/18/07	2/19/07	
Time	1111–1236	0921–1521	0736–1336	0720–1320	0721–1321	
FPM (gr/dscf)	0.0081	0.0089	0.0063	0.0064	0.0083	0.0076
CPM (gr/dscf)	0.0033	0.0029	0.0026	0.0029	0.007	0.0037
TPM (gr/dscf)	0.0114	0.0118	0.0089	0.0093	0.0153	0.0113
Load	891	835	889	906	900	
Opacity	9.2	8.6	9.9	9.6	13.1	

Table 27. B-west ESP west (PAC–redesigned injection grid) outlet PM measurements.

	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Test Date	2/15/07	2/16/07	2/17/07	2/18/07	2/19/07	
Time	1103–1234	0802–1509	0730–1330	0714–1314	0715–1315	
FPM (gr/dscf)	0.0098	0.0093	0.0047	0.0046	0.0050	0.0067
CPM (gr/dscf)	0.0026	0.001	0.002	0.0018	0.0038	0.0022
TPM (gr/dscf)	0.0124	0.0103	0.0067	0.0064	0.0088	0.0089
Load	891	853	888	906	900	
Opacity	9.2	8.8	9.9	9.6	13.1	

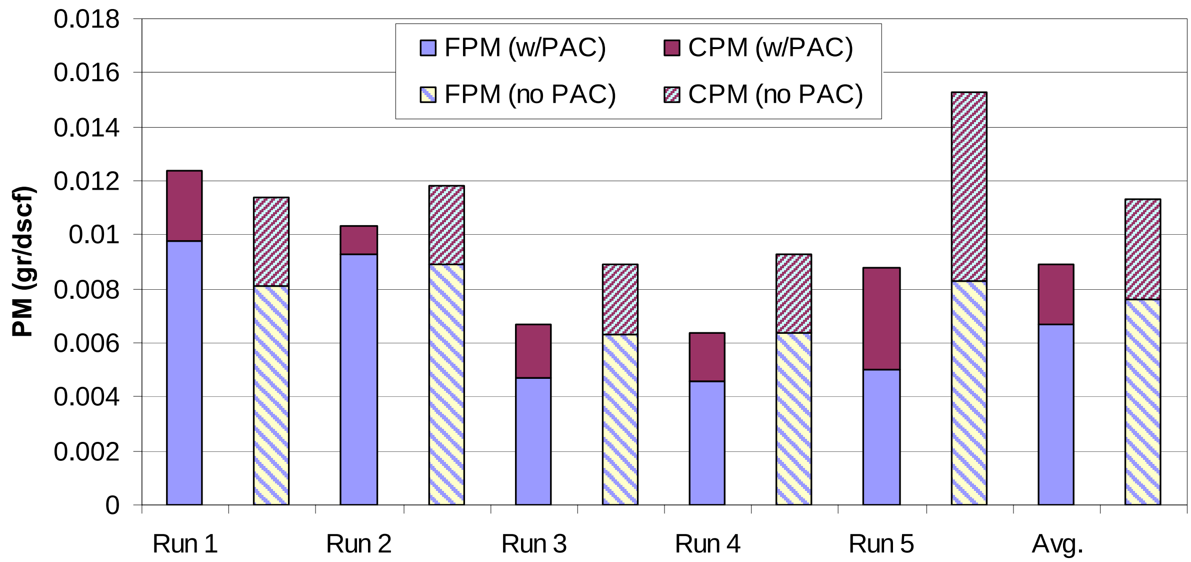


Figure 85. Summary of PM results collected at the ESP outlet with and without PAC (using redesigned injection grid).

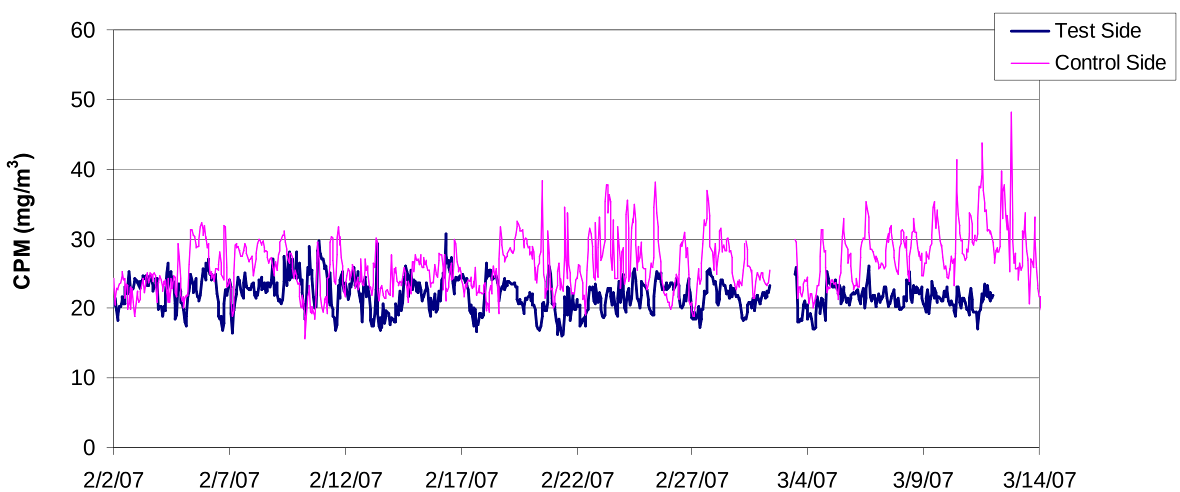


Figure 86. Trend of CPM data from B-West ESP (test—redesigned injection grid) and B-East ESP (control).

Manual Particulate Measurements

As can be seen in the data explained above concerning particulate emissions, one of the difficulties involved with the test program at Independence was determining a means to accurately measure particulate emissions. The two triggers for New Source Review (NSR) for particulate emissions at Independence are 25 tons/year PM increase and 15 tons/yr PM10 increase. The corresponding contribution of the ESP B outlet duct particulate loading that would result in an NSR is approximately 0.839 lb/hr at full load. This number was calculated by taking the required hourly particulate increase for a year divided by 8 and accounting for the annual unit capacity of 85% (Corresponding Increase (lb/hr) = (50,000 lbs/yr * 1/8 Unit)/(365 days/hr * 24 hr/day *85%)). No analysis was completed to determine particle sizing and calculate the amount of PM10 increase as a result of PAC injection.

The Method 17 test results were the initial test results from the beginning of the test sequence. The Long-Term injection concentration was 5.5 lb/MMacf through the mid-field injection grid. These numbers in Table 28 would indicate that the injection of DARCO® Hg-LH would improve the performance of the ESP and would not trigger an NSR condition. Yet a comparison of any one of the Baseline M17 results against each other or against the average (with the exception of Run 2) would in itself trigger an NSR evaluation. The same comparison holds true for the Long-Term PAC Injection M17 results.

Table 28. 2005 Baseline/injection PM testing.

2005 Method 17 Test Results from ESP B Outlet Duct				
	Run 1	Run 2	Run 3	Average
Baseline	22.10	23.45	26.60	24.05
Long-Term PAC Injection	9.85	13.66	10.12	11.21

The one-hour Method 17 testing is suspect in a test regimen such as the one used at Independence. Testing in the outlet duct of the ESP creates the conditions were the test can be artificially biased. If some of the individual tests in a test series are conducted in between rapping cycles of the outlet field (as long as four hours between outlet field rap cycles was tested at Independence), then the bias is that the tests that are carried out in the absence of rapping should indicate lower particulate emissions.

In an effort to limit potential biasing of test results, ADA-ES designed a modified Method 5 test. This test was run both at the stack and at the ESP B outlet duct (Table 29). The modification was to run the test for 6 continuous hours. The test period should allow an averaging out of all particulate emission cycles, such as the rapping cycle. The tests would also run for 5 sequential days, each day consisting of one 6-hour run, to allow a complete look at any anomalies.

Table 29. 2007 Method 5 PM Measurements.

2007 Method 5 PM Measurements — Baseline and Injection Periods (lbs/hr)							
Location	**Condition**	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Average**
Stack	Baseline	13.78	16.84	14.80	13.24	15.13	14.76
Stack	PAC Injection	15.45	17.58				16.51
ESP B Outlet Duct	PAC Injection	25.58	23.23	19.73	20.25	32.46	24.25
ESP B Outlet Duct	Control Side (No Injection)	31.91	22.56	15.84	14.48	19.24	20.81

The particulate emission rates for the stack have been divided by 8 to provide an equivalent flue gas flow measurement to the duct outlet numbers. Unlike the earlier Method 17 testing, these results indicate that the injection of DARCO® Hg-LH would increase particulate emissions and trigger the 25 tons/yr limit. Even with the attempt to normalize the emissions particulate measurements across any particulate causing events still results in a potential issue. Any day-to-day comparison of the baseline numbers would in itself potentially trigger an NSR evaluation. On the other hand, on any given day, a side-to-side comparison of the particulate emissions during PAC injection could again indicate that overall emissions decreased.

Ash Sales

One of the primary advantages of TOXECON II™ for mercury control is to preserve the bulk of the fly ash at a saleable quality. During TOXECON II™ testing at Independence, all ash captured in the first two collection fields was sold for use in concrete. This represented the bulk of the ash collected from Unit 2. The balance of the ash, that containing PAC, was landfilled after a leaching analysis was performed and the ash met criteria established by the State of Arkansas.

A question that has been discussed within the project team, based upon concerns from an ash contractor, is whether the size distribution and resulting concrete properties will be adversely affected if the rear field ash is not included in the ash delivered for concrete use. The size distribution of ash collected in the first two fields, the material available for ash sale, was analyzed and results are included in Figure 87 and Table 30. Although there is a shift from the inlet hopper (B12) o the second hopper (B22), the distribution is fairly uniform. The ash from the inlet field represents the bulk of the fly ash captured in the ESP. Ash collected in the third and fourth fields represents at most four percent of the overall ash captured and it is unlikely that not including this in the ash provided for concrete use will impact the overall properties of the ash for this use.

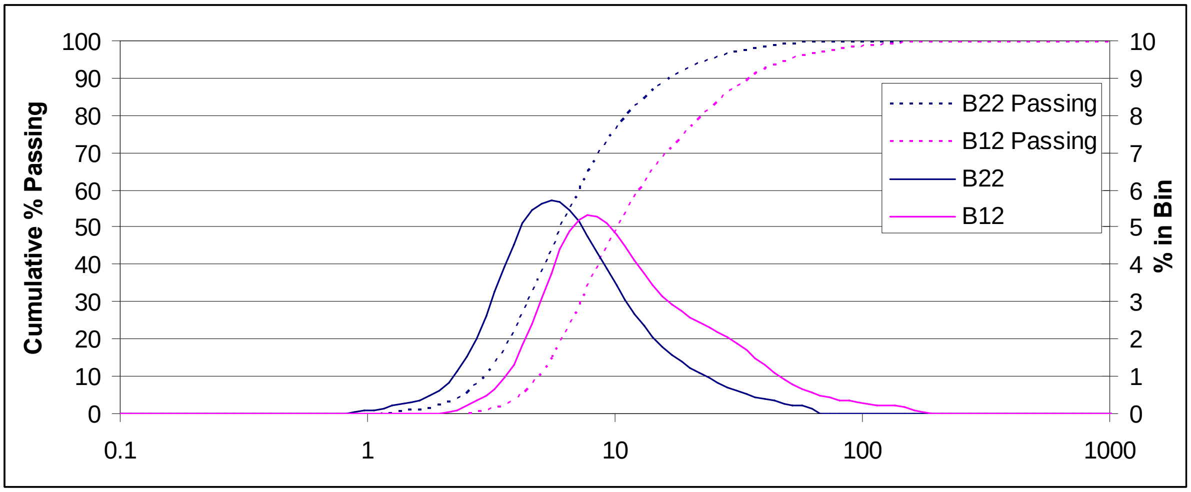


Figure 87. Size distribution of ash collected in first two fields.

Table 30. Size distribution of ash collected in first two fields.

Date	8/19/2005	8/19/2005
Location	Hopper B12 Inlet 1	Hopper B22 Inlet 2
Percent Passing	Size (µm)	Size (µm)
10	4.86	2.933
20	6.05	3.71
30	7.17	4.41
40	8.44	5.15
50	10.05	6
60	12.33	7.05
70	15.95	8.52
80	22.11	10.94
90	33.87	16.36
95	48.72	23.34

Results of Halide Measurements

Effect of DARCO® Hg-LH on Halide Emissions

To determine the halogen and hydrogen halide concentration in the flue gas, triplicate runs of the EPA Method 26A were conducted at the inlet and outlet of the ESP during the 2005 Baseline and Long-Term test periods. Results are summarized in Table 31. All values are quite low, which is representative of units firing PRB coal.

Table 31. Average values of Method 26A runs at ESP B-box.

	ESP Inlet		ESP Outlet	
	Baseline 8/17–18/2005	Long-Term 10/25–26/2005	Baseline 8/17–18/2005	Long-Term 10/25–26/2005
HCl (ppmv)	0.39	0.47	0.44	0.49
HF (ppmv)	0.83	1.62	1.53	1.58
HBr (ppmv)	0.01	0.02	0.02	0.68
Cl_2 (ppmv)	N.D.	0.02	N.D.	0.01
Br_2 (ppmv)	N.D.	0.01	N.D.	N.D.

(N.D. = none detected)

The total chlorine (HCl + Cl2) was almost unchanged from inlet to outlet for both the Baseline and Long-Term test periods. As a reference, coal samples taken on the same days as the Method 26A tests were run contained 37 µg/g Cl (Baseline) and 1 µg/g Cl (Long-Term).

The HBr noticeably increased across the ESP during the Long-Term test, from 0.02 ppmv at the inlet of the ESP to 0.68 ppmv at the outlet. As a reference, coal sampled throughout the test program contained an average of 1.3 µg/g of Br. The sorbent injected during the 30-day continuous test was treated with trace amounts of bromine compounds. The increase in HBr could be a result of a fraction of the bromine compounds released from the sorbent particle once injected into the flue gas stream. The M26A test reports are included in Appendix D.

ECONOMIC ANALYSIS

After completion of testing and analysis of the data, the requirements and costs for full-scale, permanent commercial implementation of the necessary equipment for mercury control using sorbent injection technology at the 880 MW Independence Station Unit 2 were determined. The cost of process equipment sized and designed based on the Long-Term test results for approximately 80% mercury control, and on the plant-specific requirements (sorbent storage capacity, plant arrangement, retrofit issues, winterization, controls interface, etc.) has been estimated. The system design was based on the criteria listed in Table 32.

Table 32. System design criteria for mercury control at Independence Unit 2. 5 lb/MMacf injection, > 90% mercury control.

Parameter	
Number of Silos	2
Number of injection trains	6 (2 spare)
Design feed capacity/train (lb/hr)	1920
Operating feed capacity/train (lb/hr)	960
Sorbent storage capacity/silo (lbs)	460,800
Conveying distance (ft)	200/400
Sorbent	DARCO® Hg-LH
Aerated Density (lb/ft^3)	18
Settled Density (lb/ft^3)	28
Particle MMD (microns)	18

The estimated uninstalled cost for a sorbent injection system and storage silo for the 880-MW Unit 2 is $2,730,000. Costs were estimated based on a long-term activated carbon injection concentration of 5 lb/MMacf. For Independence Unit 2, this would require an injection rate of nominally 960 lbs/hr at full load. Assuming a unit capacity factor of 85% and a delivered cost for DARCO® Hg-LH sorbent of $0.95/lb, the annual sorbent cost for injecting sorbent into the existing ESP would be about $6,791,000. This corresponds to a nominal sorbent cost of $15,850 per pound of mercury removed.

Results from the field tests conducted to date indicate different levels of mercury removal can be achieved depending on the air pollution control equipment and different flue gas conditions. Data collected from the Phase I DOE tests at Gaston indicate mercury removal levels of up to 90% were obtained with a COHPAC® (a baghouse) and DARCO® Hg sorbent injection. At Pleasant Prairie, 50 to 70% removal while injecting DARCO® Hg was the maximum achievable mercury control, with the configuration of an ESP collecting PRB ash. At Brayton Point, mercury removal levels of up to 90% were obtained with an ESP collecting bituminous ash with DARCO® Hg sorbent injection.[3] DOE Phase II testing at Holcomb showed mercury removal levels of 90% were obtained with a SDA and FF while injecting DARCO® Hg-LH.[4] Data from Independence and five other sites are summarized in Table 33.

Table 33. Summary of mercury removal efficiencies and costs for different APC configurations, coals, and sorbents.

Plant	APC Equipment	Coal	Sorbent	Removal %	Sorbent Cost (mills/kWh)
Gaston	COHPAC®	Bituminous	DARCO® Hg	90	0.43
Pleasant Prairie	ESP	PRB	DARCO® Hg	67	1.2
Brayton Point	ESP	Bituminous	DARCO® Hg	90	2.4
Holcomb	SDA + FF	PRB	DARCO® Hg-LH	90	0.44
Meramec	ESP	PRB	DARCO® Hg-LH	90	0.74
Independence	ESP	PRB	DARCO® Hg-LH	80	1.14

The results from Independence indicate that using DARCO® Hg-LH would result in higher mercury removal (80%) at less than the cost of the maximum achievable removal at Pleasant Prairie (67% mercury removal). Both units fire PRB coal and have ESPs installed for particulate control. The critical difference in the sorbent costs is the improved effectiveness of DARCO® Hg-LH over DARCO® Hg. These results are presented as mills/kWh in Table 33.

System Description

The permanent commercial activated carbon injection system for Independence will consist of two bulk storage silos and six (three per silo) dilute phase pneumatic conveying systems. Generic process diagrams and other sorbent injection system drawings are provided in Appendix A. While the basic system design will remain the same, specific components for the TOXECON II™ injection system will change as a result of extensive CFD modeling prior to commercial installation.

DARCO® Hg-LH sorbent will be received in 40,000-lb batches delivered by self-unloading pneumatic bulk tanker trucks. The silo is equipped with a pulse jet type bin vent filter to contain dust during the loading process. The silo is a shop-built, dry-welded tank with three mass flow discharge cones equipped with air fluidizing pads and nozzles to promote sorbent flow. Point level probes and weigh cells monitor sorbent level and inventory. Silo sizing was based on the capacity to hold approximately six truckloads of DARCO® Hg-LH sorbent, sufficient for 10 days of operation at the design injection rate.

The sorbent is fed from the discharge cones by rotary valves into feeder hoppers. From the hoppers the sorbent is metered into the conveying lines by volumetric feeders. Conveying air supplied by regenerative blowers passes through a venturi eductor, which provides suction to draw the sorbent into the conveying piping and carry it to distribution manifolds, where it splits equally to multiple injection lances. The blowers and feeder trains are contained beneath the silo within the skirted enclosure.

A programmable logic controller (PLC) is used to control all aspects of system operation. The PLC and other control components will be mounted in a NEMA 4 control panel. The control panel, MCCs and disconnects will be housed in a pre-fabricated power and control building located adjacent to the silo.

The system description is generic for a sorbent injection system. The actual design for the TOXECON II™ system will vary from the above description in several important categories that have not been finalized and are therefore not included in this report.

Balance-of-Plant Requirements

Some modifications and upgrades to the existing plant equipment will be required to accommodate the ACI system. These include upgrades to the electrical supply at Independence to provide new service to the ACI system. Instrument air, intercom phones, and area lighting will also be required.

It is not anticipated that the fly ash from downstream of the selected injection point from Independence can be sold if activated carbon injection is implemented. Cost estimates are included to account for the minimal (< 10%) loss of ash sales and for the increased costs of disposal.

Cost and Economic Methodology

Costs for the sorbent storage and injection equipment were provided by ADA-ES based on the design requirements in Table 32. ADA-ES has built and installed many similar systems at coal-fired power plants for mercury control. Estimated costs for the distribution manifold, piping and injection lances, an installation man-hour estimate and crane-hour estimate and an estimate for foundations including pilings are also included. As construction costs are rising rapidly, these costs are tentative and very dependent upon local labor conditions as well as current national demand for related equipment.

EPRI TAG methodology was used to determine the indirect costs. A project contingency of 15% was used. Since the technology is relatively simple, the process contingency was set at 5%. Based upon requested guarantee language, that contingency may increase to cover anticipated risks for a newer technology. ACI equipment can be installed in a few months; therefore, no adjustment was made for interest during construction, a significant cost factor for large construction projects lasting several years.

Operating costs include sorbent costs, electric power, operating labor, maintenance (labor and materials), and spare parts. An average incremental operating labor requirement of 1 hour per day was estimated to cover the incremental labor to operate and monitor the ACI system. The annual maintenance costs were based on 5% of the uninstalled equipment cost.

Levelized costs were developed based on a 20-year book life and are presented in constant dollars.

Capital Costs

The uninstalled ACI storage and feed equipment costs are estimated at $2,730,000. The estimated cost for a sorbent injection system and storage silo installed on the 880-MW Unit 2 is $4,330,000 and includes all process equipment, foundations, support steel, plant modifications utility interfaces, engineering, taxes, overhead, and contingencies. The capital and O&M costs are summarized in Table 34.

Table 34. Capital and operating and maintenance cost estimate summary for ACI system on Independence Unit 2. Annual basis 2007.

Capital Costs Summary	
Equipment, FOB Independence	2,730,000
Site Integration (materials and labor)	159,000
Installation (ACI silo and process equipment, foundations)	192,000
Taxes	185,000
Indirects/Contingencies	1,064,000
Total Capital Required	4,330,000
$/kW	4.92
Operating and Maintenance Costs Summary	
Sorbent @ $.95/lb	6,791,000
Power, labor, maintenance	185,000
Variable O&M for 2007 ($/kW)	8.74
Variable Mills/kW-hr	1.17

Operating and Levelized Costs

With the exception of the waste disposal costs, which are discussed below, the most significant operational cost of sorbent injection for mercury control is the DARCO® Hg-LH sorbent. Sorbent costs were estimated for an average of > 80% mercury control based on the long-term sorbent injection concentration of 5 lb/MMacf. For Independence Unit 2, this would require an injection rate of nominally 960 lbs/hr at full load. Assuming a unit capacity factor of 85% and a delivered sorbent cost of $0.95/lb, the 20-year levelized annual cost of injecting sorbent via a TOXECON II™ system would be $10,293,000. Included in this is other annual operating levelized costs including electric power, operating labor, and maintenance which are estimated to be approximately $236,000.

Based on these test program results and assuming that sorbent injection at the ESP inlet for mercury control is sustainable, an average of > 80% mercury control can be attained at Independence Unit 2 for an initial capital investment of $4,330,000 with first-year operating costs of $9.51/kW, or annual 20-year constant-dollar levelized costs of $11.70/kW. This information is summarized in Table 35.

The levelized costs reported in Table 34 are specific to Independence Unit 2.

Table 35. Levelized costs summary.

20-Year Levelized Costs Summary—$ Constant	
	Lost Ash Sales Revenue and Disposal Costs Not Included
Fixed Costs	367,000
Variable O&M	7,691,000
Total	10,293,000
Fixed Levelized Costs $/kW	0.58
First Year Operating Levelized Costs $/kW	9.51
Total 20-Year Levelized Costs $/kW	11.70
First-Year Operating Levelized Costs mills/kW-hr	1.28
Total 20-Year Levelized Costs mills/kW-hr	1.49
Total 20-Year Levelized Cost $/lb Hg removed	14,

CONCLUSIONS

The primary objective of testing at Entergy's Independence Steam Electric Station was to determine the cost and effects of sorbent injection using EPRI's TOXECON II™ for mercury control in stack emissions from Unit 2. Unit 2 was chosen for this evaluation because it fires PRB coal and is equipped with a medium sized, cold-side ESP (SCA = 542 ft^2/kacfm) for particulate control. General observations and conclusions include:

- Native mercury removal and speciation
  - o Less than 20% mercury removal during four rounds of Baseline testing. While firing PRB coal, the ESP B inlet mercury averaged 7.9 lb/TBtu during Baseline tests while the ESP B outlet averaged 6.6 lb/TBtu. While firing ColoWyo coal, ESP B inlet mercury averaged 1.2 lb/TBtu. Independence typically fires PRB coal.

The inlet mercury during most of the Baseline tests was primarily elemental mercury, 65–70% (SCEM) and 65% (Ontario Hydro). During most of the tests, the fraction of elemental mercury at the outlet of the ESP was 37–55% (SCEM) and 55% (Ontario Hydro), indicating some oxidation in the ESP.

- Parametric Testing
  - o DARCO® Hg-LH was the most effective sorbent evaluated at Independence during the DOE program. Short-term results indicate that 80% mercury removal was achieved at 2.4 lb/MMacf and nearly 90% at 4.8 lb/MMacf (injection between fields B-3 and B-5). Injecting downstream of field B-5 reduced mercury capture by nominally 10%.
  - o Pre-ESP DARCO® Hg-LH injection resulted in 85% mercury removal at 5 lb/MMacf with a non-optimized injection grid.
  - o During the 2005 tests, injection of any sorbent resulted in both opacity and CPM spikes. Although PAC was injected into only 1/8 of Unit 2, each time the final field was rapped during August and September while PAC was injected into either field 5 or 7, the spikes in indicated particulate emissions were clearly visible on the plant's permanently installed stack opacity monitor. Turning off the Power Optimization System and increasing ESP power in the rear fields minimized but did not completely eliminate the spikes in the CPM and Unit 2 opacity measurements during PAC injection (DARCO® Hg-LH).

- Long-Term Testing
  - o Average mercury removal during the initial 30-day Long-Term test (October 2005) was 69% and the average outlet mercury concentration was 1.91 lb/TBtu. The average DARCO® Hg-LH injection concentration during this period was 5.5 lb/MMacf.
  - o During subsequent continuous injection periods (typically 5-day or 30-day) using the TOXECON II™ injection system with modified lances, the average vapor-phase mercury capture ranged from 70–85% based on the lance design with an average sorbent injection concentration of 5–5.5 lb/MMacf.

- Balance-of-Plant
    - Increasing the ESP power and increasing the final field rapping cycle were effective at minimizing opacity spikes due to PAC injection.
    - Additional testing is required to determine whether TOXECON II™ implementation would result in a sufficient increase in particulate emissions to trigger a permit review.

The goals for the program established by DOE/NETL were to reduce the uncontrolled mercury emissions by 50 to 70% at a cost 25 to 50% lower than the target established by DOE of $60,000/lb mercury removed. This goal was exceeded at Independence. Results from testing indicated that 80% mercury removal could be achieved using DARCO® Hg-LH at a sorbent cost 75% lower than the benchmark. The estimated 20-year levelized costs for control at Independence are 1.49 mills/kWh or 14,500 $/lb mercury removed while preserving the salability of the fly ash. Additional improvements to the injection system design to increase mercury removal by improving the sorbent distribution are anticipated with ongoing development of the technology.

REFERENCES

1. Berry, Mark S., (2007). "Southern Company Generation: Mercury Control Research Program," presented at the Air and Waste Management Association Annual Conference, Pittsburgh, PA, June 27.

2. Derenne, Steven T. "TOXECON™ Retrofit for Mercury and Multi-Pollutant Control on Three 90-MW Coal-Fired Boilers." U.S. DOE Cooperative Agreement No. DE-FC26-04NT41766, Quarterly Technical Progress Report No. 41766R14, October 29, 2007.

3. "Field Test Program to Develop Comprehensive Design, Operating, and Cost Data for Mercury Control Systems." U.S. DOE Cooperative Agreement No. DE-FC26-00NT41005, Topical Report No. 41005R21, March 17, 2005.

4. Sjostrom, Sharon. "Evaluation of Sorbent Injection for Mercury Control." U.S. DOE Cooperative Agreement No. DE-FC26-03NT41986, Topical Report No. 41986R07, June 28, 2005.

LIST OF ACRONYMS AND ABBREVIATIONS

ACI	Activated carbon injection
APC	Air pollution control
CFD	Computational Fluid Dynamics
DARCO® Hg	Sorbent manufactured by NORIT Americas. Formerly known as DARCO® FGD
DARCO® Hg-LH	Sorbent manufactured by NORIT Americas. Formerly known as DARCO® FGD-E3
DOE	Department of Energy
ESP	Electrostatic precipitator
FGD	Flue gas desulfurization
kacfm	Thousand actual cubic feet per minute
kW	Kilowatt
MMacf	Million actual cubic feet
MW	Megawatt
NETL	National Energy Technology Laboratory
O&M	Operating and Maintenance
PAC	Powdered activated carbon
PC	Pulverized coal
POS	Precipitator Optimization System
PRB	Powder River Basin
RCRA	Resource Conservation and Recovery Act
SCA	Specific collection area
SCR	Selective Catalytic Reduction
S-CEM	Semi-continuous emission monitor
SDA	Spray dryer absorber
SGLP	Synthetic groundwater leaching procedure
STM	Sorbent trap method
TCLP	Toxicity characteristic leaching procedure
TR	Transformer-Rectifier

APPENDIX A:

Independence Test Plans

APPENDIX A1: Entergy Independence Test Plan—September 15, 2005

DOE NATIONAL ENERGY TECHNOLOGY LABORATORY MERCURY FIELD EVALUATION

Evaluation of TOXECON II™ Sorbent Injection for Mercury Control at Entergy's Independence Steam Electric Station

Revision 1 dated September 15, 2005 to Test Plan dated July 25, 2005

For:
Entergy
DOE NETL
EPRI

By:
ADA Environmental Solutions, Inc.
8100 SouthPark Way, Unit B
Littleton, CO 80120

August 31, 2005

Table of Contents

Test Plan Revision 1

Project Objectives 1

Project Overview 2

  Host Site Description 3

General Technical Approach 6

  Task 1. Site Coordination, Kickoff Meeting, Test Plan, and QA/QC Plan 6

  Task 2. Design and Install Site-Specific Equipment 7

  Task 3. Field-Tests – Sorbent Selection 12

  Task 4. Field-Tests – Baseline Tests 19

  Task 5. Field-Tests – Parametric Tests 19

  Task 6. Field-Tests – Long-Term Tests 21

  Task 7. Data Analysis 21

  Task 8. Sample Evaluation 21

  Task 9. Site Report 22

  Task 10. Technology Transfer 22

  Task 11. Management and Reporting 23

Schedule 24

List of Figures

Figure 1. TOXECON II™ Process Diagram. 2

Figure 2. Sketch of West Half (Elevation View) of the ESP at Independence Unit 2. 4

Figure 3: ESP Electrical Field and Ash Hopper Configuration. 5

Figure 4: Carbon Injection Storage Silo and Feeder Trains Installed at Sunflower Electric's Holcomb Station 9

Figure 5: Sketch of Mercury Measurement System. 11

Figure 6: Parametric Test Results for DARCO Hg and DARCO Hg-LH 13

Figure 7: Current Schedule for the Independence Test Program 24

List of Tables

Table 1. Host Sites Participating in the Sorbent Injection Demonstration Project. 3

Table 2. Independence Key Operating Parameters. 4

Table 3. Site-Specific Tasks 6

Table 4. Scopes of Work for Sorbent Injection System 8

Table 5. Full-Scale Test Sequence During August. 14

Table 6: Scheduled Full Scale Test Sequence 15

Table 7: Completed Test Matrix for Baseline and Parametric Test Series 16

Table 8: Scheduled Test Matrix 17

Table 9. Key Project Personnel for Independence Mercury Field Evaluation. 25

Test Plan Revision

During Baseline testing per the original Test Plan, the plant reported that electrical field 7 of ESP B was down, isolated to an apparent ash build up on the field, probably caused by a rapper motor failure. Field 7 is the outlet field on the test side of ESP B, see Figure 3. Since TOXECON II^{TM} is an injection technology involving mid-ESP sorbent injection, the loss of the outlet field, normally not of significant import to sorbent testing, would impact quality data collection. As a result of this failure, it was determined to run a shortened series of Parametric tests and delay further testing until repairs could be effected late in September.

Project Objectives

The objective of testing at Entergy's Independence Steam Electric Station (ISES) is to determine the cost and effects of sorbent injection using EPRI's TOXECON II™ process for control of mercury in stack emissions.

The benefit of the TOXECON II™ process, shown in Figure 1, *TOXECON II™ Process Diagram*, is that the ESP collects the majority of ash before the injection of the mercury control sorbent into the flue gas stream. With TOXECON II™ , the sorbent injection is between the fields of an existing electrostatic precipitator (ESP), generally after the first two fields, and the ash handling system segregates the untreated ash from the treated sorbent/ash mixture. This allows the ash collected in the ESP fields upstream of sorbent injection to be sold for use in concrete.

This evaluation will test one-eighth of the 842 MW flue gas stream from Unit 2.

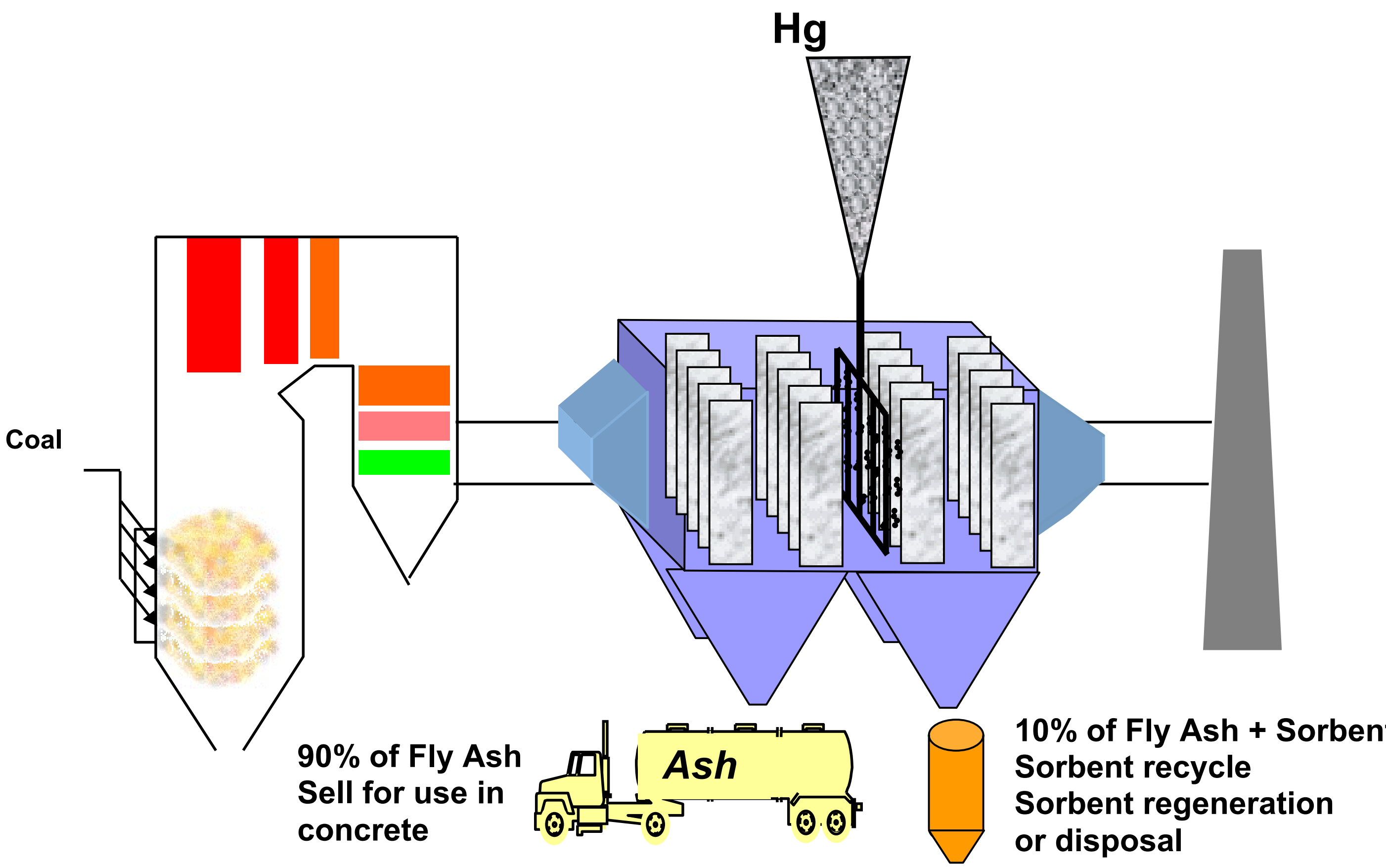


Figure 1. TOXECON II™ Process Diagram.

Project Overview

The Entergy Independence test program is part of a four-site program funded by the Department of Energy's National Energy Technology Laboratory (DOE/NETL) and industry partners to obtain the necessary information to assess the feasibility and costs of controlling mercury from coal-fired utility plants using either high temperature sorbents or EPRI's TOXECON II™ process. Table 1, *Host Sites Participating in the Sorbent Injection Demonstration Project*, shows the host sites for this program's testing. Testing at these four host sites will allow documentation of sorbent performance on the following configurations:

Table 1. Host Sites Participating in the Sorbent Injection Demonstration Project.

	Coal / Options	APC	Capacity (MW) / Test Portion	Current Hg Removal (%)
Entergy's **Independence Station Unit 2**	PRB	Cold-Side ESP	842/106	10-20%
MidAmerican's **Louisa Station Unit 1**	PRB	Hot-Side ESP	700/350	<10% (Estimated)
MidAmerican's **Council Bluffs Station Unit 2**	PRB	Hot-Side ESP	88/88	<10% (Estimated)
AEP's **Gavin Station Unit 1 or 2**	Bit	Cold-Side ESP / FGD	1,200/200	0% ESP, 70%+ in FGD

The test program selected Independence Unit 2 as one of the test sites because it has a large four-field ESP (SCA = 542 ft^2/kacfm) and fires PRB coal. This combination will allow an evaluation of the TOXECON II™ process in two configurations:

- Sorbent injection between the second and third ESP fields with an effective SCA of approximately 270 ft^2/kacfm to collect the sorbent.
- Sorbent injection between the third and fourth ESP fields with an effective SCA of approximately 135 ft^2/kacfm to collect the sorbent.

Host Site Description

The Independence Steam Electric Station is located in Independence County, Arkansas. Unit 2 is an 842-MW (gross) pulverized coal, electric generating unit with Lungstrum regenerative air preheaters that burns PRB coal. Table 2*, Independence Key Operating Parameters*, shows the key operating parameters for Independence Unit 2.

Table 2. Independence Key Operating Parameters.

Unit	2
Size (MW)	842
Test Portion (MWe)	106
Coal	PRB
Heating Value (as received)	8,700
Sulfur (% by weight)	0.32
Chlorine (%)	~0.01
Mercury (µg/g)	0.04
Particulate Control	Cold-Side ESP SCA = 542 ft^2/kacfm
Sulfur Control	Compliance Coal
Air Pre-Heater	Regenerative
Ash Reuse	Sold

Independence Unit 2 is equipped with four ESPs in a piggyback configuration, with two boxes on top and two boxes on the bottom, operating in parallel for particulate removal. Figure 2, *Sketch of West Half of the ESP at Independence Unit 2*, shows a sketch of one-half of the Unit 2 flue gas path. The figure shows two injection locations.

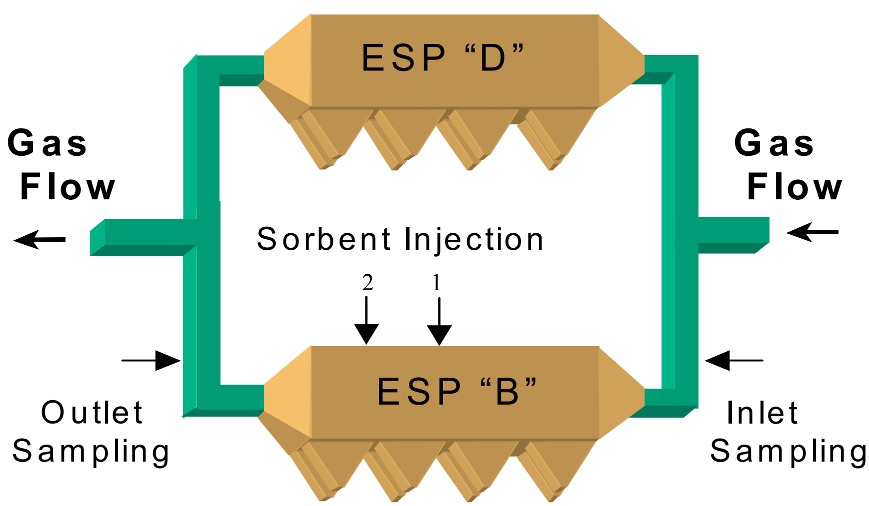
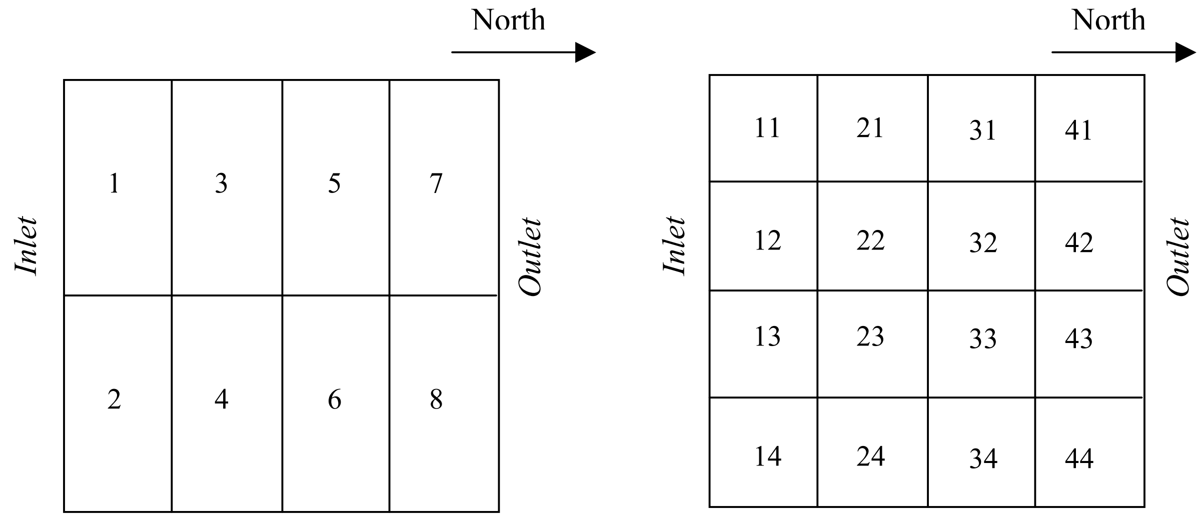


Figure 2. Sketch of West Half (Elevation View) of the ESP at Independence Unit 2.

Each ESP has eight electrical fields: four front to back and two side to side, and 16 hoppers: four front to back and four side to side.   See Figure 3, *ESP Electrical Field and Ash Hopper Configuration*.



ESP Electrical Fields   ESP Ash Hoppers

Figure 3: ESP Electrical Field and Ash Hopper Configuration.

The test program will inject sorbent between the ESP fields on one-eighth of the 842 MW flue gas stream. The first injection location is between precipitator electrical fields 3 and 5, and the second is between precipitator electrical fields 5 and 7. The test side of ESP B is designated as “test” side, the control side is “control” side, with the same numbering configuration.

General Technical Approach

The test program activities for each test site consist of the eleven tasks shown in Table 3, *Site-Specific Tasks.* These tasks provide the outline for the test plan.

Table 3. Site-Specific Tasks.

Task	Description
1.	Site Coordination, Kickoff Meeting, Test Plan, and QA/QC Plan
2.	Design and Install Site-Specific Equipment
3.	Field-Tests – Sorbent Selection
4.	Field-Tests – Baseline Tests
5.	Field-Tests – Parametric Tests
6.	Field-Tests – Long-Term Tests
7.	Data Analysis
8.	Sample Evaluation
9.	Site Report
10.	Technology Transfer
11.	Management and Reporting

Following are the task descriptions for the Entergy Independence testing:

Task 1. Site Coordination, Kickoff Meeting, Test Plan, and QA/QC Plan

Efforts within this task include planning the site-specific tests with Entergy, the Independence Power Plant, DOE/NETL, and the contributing team members. ADA-ES met with Entergy and Independence plant personnel on November 10, 2004, to discuss the overall scope of the program, the potential impact on plant equipment and operation, and identify potential equipment and port locations. ADA-ES conducted additional communications with Entergy to discuss the host site agreements and team member cost-sharing arrangements. ADA-ES and Entergy will finalize these efforts during this task. Other efforts include identifying any permit requirements, developing a quality assurance/quality control plan, developing a site specific installation document, finalizing the site-specific scope for each of the team members, and putting subcontracts in place for manual (Ontario Hydro, Particulate, etc.) sampling services.

Test Plan

This document is the Test Plan for the project testing at Entergy's Independence Station.

QA/QC Plan

ADA-ES personnel and subcontractors will be performing the various sampling and analytical functions required to evaluate the effectiveness of the mercury controls. All testing personnel will be required to adhere to written QA/QC procedures. QA/QC procedures will be prepared as part of separate detailed QA/QC plan that will be submitted for approvals ahead of Long Term testing dates by Entergy/Independence and DOE. The plans will include the necessary QA/QC activities that are required to assure the validity of collected data. At a minimum, the QA/QC Plan will include a description of the test methods to be used: instrument/equipment testing; maintenance and inspection procedures; instrument calibration and frequency; inspection/acceptance requirements for supplies and consumables; procedures for checking data reduction and validation; and sample handling and chain of custody requirements. Standard methodologies and procedures have been established for all the methods to be used in the testing, therefore any new or unproven techniques will be noted as such when presenting information to the project.

Initial Sorbent Selection

A key component of the test planning process for these evaluations is identifying potential sorbents for testing. The test program anticipates the full-scale evaluation of two different sorbents. NORIT Americas' DARCO Hg, a lignite-derived activated carbon is considered the benchmark for these tests because of its wide use in previous and ongoing DOE and EPRI sponsored testing. Potential alternate sorbents include those that may achieve higher mercury removal than DARCO Hg or sorbents that are equally as effective but lower cost. For example, halogenated sorbents such as those tested at Holcomb, Meramec, and Laramie River Station under the DOE/NETL Phase II program (DE-FC26-03NT41986) have demonstrated improved effectiveness on low-rank and high PRB blend sites.

Task 2. Design and Install Site-Specific Equipment

Site-specific equipment includes the sorbent distribution header and sorbent injection grid installed between the ESP fields. ADA-ES engineers worked with plant personnel to design four injection grids and were on-site during installation activities. The installation contractor installed two sets of injection grids in the west half of the Unit 2B ESP; one set of two grids between precipitator fields B3 and B5 and the other set between precipitator fields B5 and B7.

Additional site support from the Independence plant includes installation of required platforms and scaffolding, supplying compressed air and electrical power, wiring plant signals including boiler load to the silo control panel, and balance of plant engineering. Table 4, *Scopes of Work for Sorbent Injection System*, presents a representative split of responsibilities on key equipment and activities between ADA-ES and the host plant.

Table 4. Scopes of Work for Sorbent Injection System.

ADA-ES	Host Site
Injection Silo and Feeder, delivered and erected on Entergy's foundation.	Injection Silo and Feeder Foundation and power
Conveying Hose (400 ft)	Injection Manifolds and Grids
PLC Controls	Test ports
Hg and Particulate SCEMs	Access platforms
Office Trailers (2)	Installation labor, other than silo erection
Coordination of Sorbent Ordering and Delivery	Compressed air
	Electrical power
	Signal Wiring / Telephones / Power
	Collection of Coal and Ash Samples
	PI System Information Trend Database
	PI Data Collection
	EMO Testing Unit Load Coordination
	Coordinate Test Program Technical Needs from Entergy

Entergy will supply and install the foundation for the silo and injection skid. ADA-ES engineers have provided the silo foundation design requirements to Entergy.

ADA-ES will oversee installation and system checkout of the overall sorbent injection system equipment and will be responsible for general maintenance of the systems during testing. At least one engineer or technician who is solely dedicated to the operation of the equipment will be on-site or on-call for all tests. The actual equipment installation, not including preparation tasks, is estimated to take three weeks. This includes time for checkout and troubleshooting. ADA-ES will also install the mercury monitors.

Independence will be responsible for all permitting and any regulatory variance requirements. ADA-ES can assist by providing information to or meeting with regulatory agencies as required.

The site-specific equipment for this test includes the following:

Sorbent Injection System

The sorbent injection system (Figure 4, *Carbon Injection Storage Silo and Feeder Trains Installed at Sunflower Electric's Holcomb Station*, shows a system installed at Sunflower Electric's Holcomb Station) consists of a bulk-storage silo and twin blower/feeder trains. The unit is approximately 50 feet high and 10 feet in diameter with an empty weight of 10 tons. The silo will hold 20 tons of sorbent. The injection blowers and feeders set underneath the storage silo.

Figure 4: Carbon Injection Storage Silo and Feeder Trains Installed at Sunflower Electric's Holcomb Station.

Pneumatic trucks deliver and unload the powdered activated carbon (PAC) sorbent into the silo, which is equipped with a bin vent bag filter. The sorbent feeds from the bottom of the storage silo through a rotary valve, into a small surge hopper (one for each feeder train), and then into the feed system.

The sorbent injection system for this testing has two delivery trains. Each train includes a variable speed screw feeder to meter the sorbent into a blower-driven eductor that then transports the sorbent (dilute phase) to the injection point. A regenerative blower on each delivery train provides the conveying air. A flexible hose carries the sorbent from the feeders to distribution headers that feed the injection grids.

It was decided to run Parametric testing using a portable Porta-PAC, leased from Norit, to expedite sorbent changes. This would allow the optimum amount of flexibility during Parametric testing to respond to on-site testing findings.

The Independence ESP has two sets of two injection grids. Each grid consists of eight injection lances connected by a common header located within the ESP. Each delivery train will feed one header/grid assembly. The single feed connection to each grid manifold runs through the ESP support insulator enclosure and then into the precipitator. The conveying hose connects to the injection manifold connection located on the outside of the insulator enclosure.

A PLC system controls the system operation. The sorbent injection system allows controlling the sorbent feed rate either manually through an HMI interface in the control trailer, or automatically through a load following signal from the plant such as unit MW load or flue gas flowrate.

Mercury Monitoring System

The test program will use at least two mercury monitoring systems to provide real-time feedback of the mercury levels in the flue gas during baseline and sorbent injection testing. The monitoring systems consists of a sample extraction and conditioning system and the analyzer system, connected with a heated sample transport umbilical bundle. The ADA-ES analyzers consist of a cold vapor atomic absorption spectrometer (CVAAS) coupled with a gold amalgamation system (Au-CVAAS). Figure 5, *Sketch of Mercury Measurement System*, shows a sketch of the system.

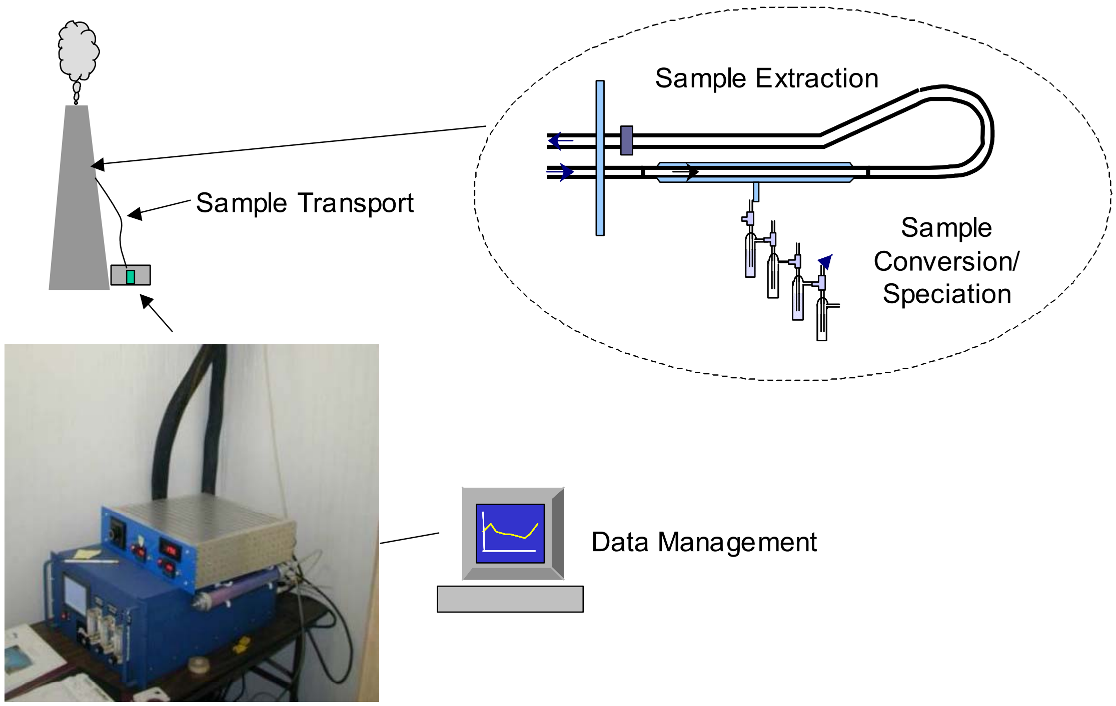


Figure 5: Sketch of Mercury Measurement System.

The figure shows an inertial separation probe. This probe separates the particulate matter from the sample with minimal sampling artifacts from fly ash or injected sorbent.

The system uses vapor-phase elemental mercury for analyzer calibration.

The monitoring system measures both *total* vapor-phase mercury and *elemental* vapor-phase mercury. The system determines *total* vapor-phase mercury concentrations by chemically reducing all of the oxidized mercury to the elemental form near the extraction location. To measure *elemental* mercury, the system removes the oxidized mercury from the sample gas while allowing elemental mercury to pass through without alteration. The oxidized mercury is then the difference between the *total* mercury measurement and the *elemental* mercury measurement.

Particulate Monitor

The test program will use particulate monitors to characterize the ESP outlet flue gas particulate emissions during baseline testing and sorbent injection. The particulate emissions data will help quantify the effects of injecting sorbent on ESP collection efficiency.

The test program will use two different particulate monitors. These include:

- <u>TEOM 7000</u>, Thermo Electron. The TEOM Series 7000 Source Particulate Monitor is an in-situ device that provides a direct measurement of the particulate matter (PM) concentration in a flue gas stream. The mass transducer with its collection filter is inside of the duct or stack, and provides results in real time. The Series 7000 monitor performs its filter-based mass measurement using an industrially-hardened tapered element oscillating microbalance. This system has received conditional test method approval for USEPA Methods 17 and 5 (front half) and meets all of the requirements of the new American Society of Testing and Materials (ASTM) Standard Test Method D6831-02. The design of this instrument is for short-term unattended operation and thus it requires pulling the probe from the duct every few days to change the filter element. By changing the position of the extraction probe location in the duct, the system can measure the particulate concentration at various locations inside of the duct, thus allowing an evaluation of particulate stratification.

- CPM 5000, BHA Group (GE). The CPM 5000 series is an across-the-stack optical measurement device that measures particle flow with a beam of visible light through which the particles travel. When dust particles pass between the transmitter and receiver, the momentary blockage of light by the particles causes the receiver to see a modulating signal from the transmitter. The amplitude of the signal modulation increases with increasing dust concentration. The signal modulation is proportional to dust concentration. CPMs are sensitive to particle size distribution and particle characteristics. In addition, CPMs do not measure mass and therefore must be calibrated using EPA Method 5 or 17. While the system cannot measure the particulates at a single point, it does measure the particulates crossing the light path, so the measured particulates are a representation of the dust loading across the duct.

Task 3. Field-Tests – Sorbent Selection

The test program participants will select the sorbents for Independence based upon results from other sites similar to Independence Unit 2 (e.g., similar sulfur and halogen concentrations in the flue gas, similar operating temperature). The test program will test DARCO Hg as the benchmark sorbent for comparison and test DARCO Hg-LH as the second sorbent based on its potential to more economically remove mercury at Independence.

Recent testing of these two sorbents at AmerenUE's Meramec Station (DOE Contract DE-FC26-03NT41986) gave the following results (Meramec fires PRB coal and has a 320 ft^2/kacfm SCA cold-side ESP):

DARCO Hg is a non-chemically treated activated carbon Texas-Lignite coal derived sorbent, and has a bulk density of 25-30 lbs/ft^3. Results from Meramec testing with DARCO Hg demonstrated an upper limit of not more than 80% mercury removal which is similar to results from other cold-side ESP sites burning low-rank coals (PRB and North Dakota lignite). While halogen species, such as HCl, appear to enhance the performance of activated carbon, halogen concentrations are relatively low in low-rank coals. It appears that activated carbon injection rates of 3 to 10 lb/MMacf are sufficient to absorb the available halogens so that further increases in injection rates do not increase mercury removal.

DARCO Hg-LH is a brominated activated carbon. Results from Meramec testing with an injection concentration of 0.6 lb/MMacf show the total mercury removal was 78%. This increased to 97% removal at 3.2 lb/MMacf. The maximum mercury removal based on the change in the ESP outlet mercury concentration due to DARCO Hg-LH injection was 91% at 3.2 lb/MMacf. These data, shown in Figure 6, *Parametric Test Results for DARCO Hg and DARCO Hg-LH*, clearly demonstrate that using halogenated activated carbon can enhance mercury removal.

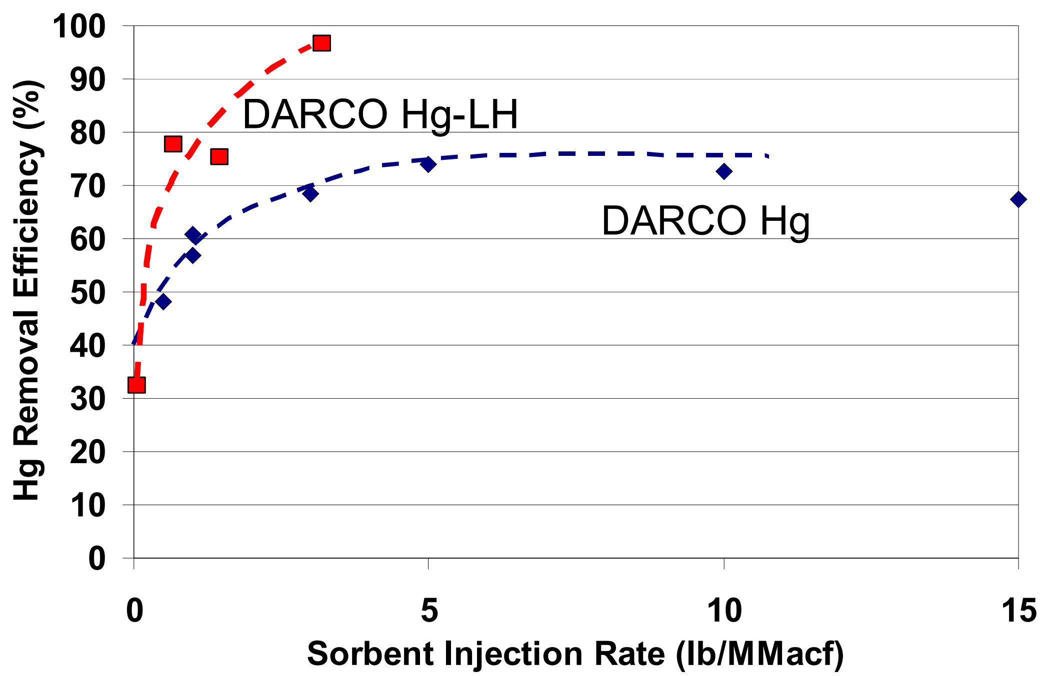


Figure 6: Parametric Test Results for DARCO Hg and DARCO Hg-LH.

Reducing the sorbent usage requirements is an important consideration for a TOXECON II™ configuration because of the small SCA available to collect the material. Data from Meramec indicates that using a halogenated sorbent may result in much higher mercury removal at lower injection concentrations.

Testing with these two sorbents will give a correlation between the mercury removal using the full ESP available collection area (such as at Meramec) and using only a part of the ESP available collection area (such as with the TOXECON II™ configuration at Independence).

Two additional sorbents will be tested to evaluate particulate pass through for the ESP fields. The first additional sorbent is Darco Hg E-10 which is a classified version of the Darco Hg, meaning the small fines are removed from the sorbent. Darco Hg E-11 is another version of Darco Hg with a larger mean particle size. Both these sorbents will be tested when injecting between ESP fields 5 and 7 to evaluate particulate pass through.

Task 4, 5, and 6.

Tasks 4, 5, and 6 are the actual field testing efforts to collect data to quantify the mercury removal. Table 5*, Full-Scale Test Sequence During August*, below, outlines the testing performed to date. Table 6, Scheduled Full Scale Test Sequence, outlines the testing scheduled for the remainder of the program. Table 7, *Completed Test Matrix for Baseline and Parametric Test Series*, details the testing that has occurred. Table 8, *Scheduled Test Matrix,* details the testing scheduled to occur. See the description of project Tasks 4, 5, and 6 below for further detail of the scope of each of these tasks.

Table 5. Full-Scale Test Sequence During August.

Test Description	Test Week	Parameters/Comments	Boiler Load
Baseline	Week 1 Aug 15 – Aug 21	Day 1 – Baseline Day 2 – Baseline Day 3 – ASTM M6784-02, M26a, M5 Day 4 – ASTM M6784-02, M26a, M5 Day 5 – Baseline Day 6, 7 – Baseline	Full Load 10AM-10PM
Parametric testing DARCO Hg	Week 2 Aug 22 – Aug 25	Day 1 – DARCO Hg: 3, 6 lb/MMacf, Location 1[a] Day 2 – DARCO Hg-LH: 1, 3, 6 lb/MMacf, Location 1 Day 3 – DARCO Hg E-10: 3, 6 lb/MMacf, Location 1 Day 4 – DARCO Hg E-11: 3, 6 lb/MMacf, Location 1 (Monitor particulate emissions and ESP electrical conditions during all tests)	Full Load 10AM-10PM
Test Delay			

[a] Location 1 is between fields 3 and 5
[b] Location 2 is between fields 5 and 7

Table 6: Scheduled Full Scale Test Sequence

Test Description	Test Week	Parameters/Comments	Boiler Load
Baseline Sept 27, – Sept 30	Week 3	Day 1 – Equipment Set Up Day 2 – Baseline Day 3 – Baseline Day 4 – Baseline (Monitor particulate emissions and ESP electrical conditions during all tests)	Full Load 48hr Full Load run requested during Baseline
Parametric testing Oct 1 - Oct 2	Week 3	Day 5 – DARCO Hg E-10: 3, 6 lb/MMacf, Location 2[b] Day 6 – DARCO Hg E-11: 3, 6 lb/MMacf, Location 2 (Monitor particulate emissions and ESP electrical conditions during all tests)	Full Load 10AM-10PM
Parametric testing Oct 3 – Oct 8	Week 4	Day 1 – DARCO Hg: 1, 3 lb/MMacf, Location 2 Day 2 – DARCO Hg: 6, 8 lb/MMacf, Location 2 Day 3 – DARCO Hg-LH: 0.5, 1 lb/MMacf, Location 2 Day 4 – DARCO Hg-LH: 3, 6 lb/MMacf, Location 2 Day 5 – PAC TBD[c]: TBD, Location 1[a] and 2 Day 6 – PAC TBD: TBD , Location 1 or 2, Dual (Monitor particulate emissions and ESP electrical conditions during all tests)	Full Load 10AM-10PM
Long-term tests Oct 10 - Nov 10	Weeks 5-9	Operate at consistent injection concentration 24 hours a day, 30 days while load following. Conduct ASTM M6784-02 weeks 2,3,4; M26A, and, M5 tests during week 3. Sorbent is Darco Hg-LH and concentration TBD based on testing results. Location (1 and/or 2) TBD	Full Load only during Ontario Hydro
Ash Recycle Nov 14 – Nov 17	Week 10	Day 1 – 4: Recycle Ash collected during Long Term at concentrations TBD	Full Load 10AM – 10PM

Table 7: Completed Test Matrix for Baseline and Parametric Test Series

August	Testing Day	PRB	PRB w/ Blend	Set Up	Baseline	Parametric	Darco Hg mid field	Darco Hg Back field	Darco Hg-LH mid field	Darco Hg-LH back field	Darco E10	Darco E11	Dual Field Injection	ADA Traverse	SCEM	STM inlet	STM Outlet	OH	Method 5	Method 26A	CPM 5000	TEOM7000
1	**1**	**X**		**x**																		
2	**2**	**X**		**x**																		
3	**3**	**X**		**x**										**x**								
4	**4**	**X**		**x**										**x**								
5	**5**	**X**		**x**										**x**	**x**						**x**	**x**
8	**6**	**X**		**x**											**x**						**x**	**x**
9	**7**	**X**		**x**											**x**	**2**	**2**				**x**	**x**
10	**8**	**X**		**x**											**x**		**1**				**x**	**x**
11	**9**	**X**		**x**											**x**		**1**				**x**	**x**
12	**10**	**X**		**x**											**x**						**x**	**x**
15	**11**	**X**			**x**										**x**						**x**	**x**
16	**12**	**X**			**x**										**x**		**2**	**x**	**x**	**x**	**x**	**x**
17	**13**	**X**			**x**										**x**		**2**	**x**	**x**	**x**	**x**	**x**
18	**14**	**X**			**x**										**x**		**2**	**x**	**x**	**x**	**x**	**x**
19	**15**	**X**			**x**										**x**						**x**	**x**
22	**16**	**X**				**x**	**3,6**								**x**						**x**	**x**
23	**17**	**X**				**x**			**1,3,6**						**x**						**x**	**x**
24	**18**	**X**				**x**					**3,6**		**x**		**x**						**x**	**x**
25	**19**	**X**				**x**						**3,6**			**x**		**3**	**3**			**x**	**x**
September	**Comment**	Coal	Coal Blend		Full Load 1000-2200	Full Load 1000-2200	Injection Rate lb/MMacf				Mid field only	Mid Field Only		Determine Sample Ports		2=dual sample, 1=single sample						

Table 8: Scheduled Test Matrix

Testing Day	PRB	Set Up	Baseline	Parametric	Long Term	Darco Hg mid field	Darco Hg Back field	Darco Hg-LH mid field	Darco Hg-LH back field	Darco E10	Darco E11	Dual Field Injection	Ash Recycle	SCEM	STM inlet - outlet	OH	CPM 5000 / TEOM 7000
19	X	x															
20	X		x											x	2,2		x
21	X		x											x			x
22	X		x											x	3,3		x
23	X			x						3,6				x			x
24	X			x							3.6			x			x
25	X			x			1,3							x			x
26	X			x			6,8							x			x
27	X			x					0.5,1					x	2,2		x
28	X			x					3,6					x			x
29	X			x				4	4					x			x
30	X			x				4	(4)			4		x			x
31	X													x			x
32	X				x				TBD					x			x
33	X				x				TBD					x			x
34	X				x				TBD					x	2,2		x
35	X				x				TBD					x			x
36	X				x				TBD					x			x
37	X				x				TBD					x			x
38	X				x				TBD					x			x
39	X				x				TBD					x			x
40	X				x				TBD					x	0,2	x	x
41	X				x				TBD					x	2,2	x	x
42	X				x				TBD					x			x
43	X				x				TBD					x			x
44	X				x				TBD					x			x
45	X				x				TBD					x			x
46	X				x				TBD					x			x
47	X				x				TBD					x	0,2	x	x
48	X				x				TBD					x	2,2	x	x
49	X				x				TBD					x			x
50	X				x				TBD					x			x
51	X				x				TBD					x			x
52	X				x				TBD					x			x
53	X				x				TBD					x			x
54	X				x				TBD					x	0,2	x	x
55	X				x				TBD					x	2,2	x	x
56	X				x				TBD					x			x
57	X				x				TBD					x			x
58	X				x				TBD					x			x
59	X				x				TBD					x			x

60	**X**				**x**				**TBD**					**x**			**x**
61	**X**				**x**				**TBD**					**x**			**x**
62	**X**												**x**	**x**	**2,2**		**x**
63	**X**												**x**	**x**			**x**
64	**X**												**x**	**x**			**x**
Comment	Coal		Full Load 1000-2200	Full Load 1000-2200	Injection Rate lb/MMacf				Back field only	Back Field Only		Determine Sample Ports			2=dual sample, 1=single sample	Week 3 LT: Method 5,26A	

Task 4. Field-Tests – Baseline Tests

Baseline testing (no sorbent injection) will commenced shortly after installation of the PAC injection and testing equipment and will continue during further testing. During the baseline testing series, the test program will perform mercury measurements at the inlet and outlet of the “B” ESP and will use these data to characterize native mercury capture across the ESP without sorbent injection. The Unit will operate at conditions expected during the Parametric tests. Normally, this includes holding the boiler load constant at full-load and operating the ESP equipment under standard full-load conditions. During this Task, the test program performed ASTM M6784-02 (mercury), M26A (HCl and HF), and particulate (EPA Method 5 or 17) measurements in conjunction with performing continuous mercury measurements using the mercury monitors and particulate measurements using the particulate monitors.

An evaluation will be made during this test series to install a third mercury monitor probe on the ESP outlet control side to monitor mercury levels without sorbent injection on a real time basis.

The test program will include installing two continuous particulate monitors at the outlet of the ESP to monitor the impact of sorbent injection on ESP particulate performance.

Task 5. Field-Tests – Parametric Tests

The test program will conduct two weeks of parametric tests following baseline testing, as shown in Table 5 and Table 6. During the continuing series of Parametric testing, the test program will evaluate the performance of the benchmark sorbent, DARCO Hg, at four injection concentrations and two injection locations. Continuing testing, the test program will evaluate a brominated activated carbon sorbent, DARCO Hg-LH, at similar test conditions as DARCO Hg. In addition, two enhanced Darco Hg sorbents, E-10 and E-11, will be evaluated to correlate particulate pass through against the benchmark Darco Hg.

The goal of the parametric test sequence is to develop a relationship between sorbent injection concentration and mercury removal efficiencies across the ESP. The test program will develop a correlation between sorbent injection concentration and ESP operation (power, spark rate, etc., and particulate emissions from the ESP) during this task.

One of the key ways to reduce the cost of a sorbent-based mercury control technology is to recycle the sorbent. Injecting PAC in a once through mode uses only a small fraction of activated carbon’s sorption capacity. In a TOXECON II™ configuration, we expect the sorbent/fly ash mixture collected in the downstream ESP fields to be high in the sorbent fraction (i.e., near 50% compared to a very low sorbent fraction of 1%–2% where the sorbent injection is ahead of the entire ESP).

The test program will collect samples of the ash/sorbent mixture from downstream of sorbent injection and analyze them for sorbent fraction. It will then assess the viability of re-injecting this material as-is into the ESP and the impacts this will have on the injection system operation, ESP operation, and mercury emission levels.

During sorbent injection testing, the plant ash handling system will route the ash from the hoppers downstream of the sorbent injection fields to the alternate ash silo (31, 32 and 41, 42, or 41, 42). If it is possible to re-inject this material, the test program will allocate one day of testing during the parametric test sequence to re-inject the material from the alternate ash silo.

The test program will conduct the parametric tests at plant full-load operating conditions. The test program will perform mercury measurements with the mercury monitors and particulate measurements with the continuous particulate monitors during the parametric tests.

Upon completion of the parametric testing, the test team (Entergy, ADA-ES, DOE, EPRI) will review the parametric testing results to determine the optimum long-term testing sorbents and conditions.

Task 6. Field-Tests – Long-Term Tests

The test program will conduct the long-term testing at the "optimum" settings as determined in the parametric tests and approved by both DOE and Entergy/Independence. It is the intent of DOE that these settings represent the most cost-effective condition for mercury removal. The goal of this task is to obtain sufficient data on mercury removal efficiency and determine the effects of PAC injection on the ESP operations, effects on byproducts, and impacts to the balance of plant equipment over a four-week period to assess viability of the process and determine the process economics.

During the long-term test period, the test program will conduct ASTM M6784-02 (Ontario Hydro) speciated mercury measurements during three distinct periods. Other tests include EPA M26A (if DARCO Hg-LH is the long-term test sorbent), and M5 or M17 particulate measurements at the inlet and outlet of the pollution control device.

This task is the single most important step in gaining acceptance from the utility industry as to the practical implementation of mercury removal technologies on coal-fired power plants using the TOXECON II™ process.

Task 7. Data Analysis

The goal of the data collection and analysis for this program is to measure the effect of sorbent injection on mercury control and the impact on the existing ESP. The test program will characterize mercury levels and plant operation with and without sorbent injection and use the results from the long-term evaluation to identify effects that may not be immediately obvious during the actual testing.

Task 8. Sample Evaluation

The test program will collect coal and combustion byproduct samples throughout the testing period. The program will analyze selected samples to better characterize mercury removal performance and factors that may influence this performance. Coal analyses will include ultimate and proximate analyses, as well as mercury and chlorine content. The ash analysis will include mercury and other possible tests such as alkalinity, size distribution, chlorine, fluorine, and metals such as selenium and arsenic.

Ash testing will also include standard leaching test methods such as the Toxicity Characteristic Leaching Procedure (TCLP, SW846-1311) and synthetic groundwater leaching procedure (SGLP). If the long-term tests use a chemically treated sorbent, the team will use SGLP to analyze for leaching of the chemical used in the treatment process.

Previous results from other programs have shown that the ash byproducts mixed with activated carbon are highly stable. However, it is important to continue evaluating these byproducts for each condition using well-established and documented techniques, and new techniques designed to perform even more robust analyses of the byproducts.

DOE has a test program planned to evaluate the stability of mercury on coal combustion byproducts. The test program will provide ash samples to the DOE contractor for analysis. The program will also collect and archive additional ash for other tests, including EPA, DOE, and EPRI requested tests, and independent DOE and Entergy approved companies.

The test program requires a sample and data management process for tracking a large quantity of samples from various process streams during the testing efforts. ADA-ES has developed a Sample and Data Management System (SDMS) that will store test data from the evaluation. The SDMS data can be used to generate reports, track sample history, and input results from laboratory analyses.

For data control and security, the system limits full access to the project manager and site manager at ADA-ES and the sample manager. Operators collecting samples will upload information to the database and print sample labels and Chain-of-Custody forms. ADA-ES will include testing results with regularly issued reports to the test team.

Task 9. Site Report

The test program will prepare a site report documenting measurements, test procedures, analyses, and results obtained in Tasks 3, 4, and 5. This report is a stand-alone document providing a comprehensive review of the testing. The test program will submit this report to the host utility. The report will also include a section on the initial economics for full-scale permanent commercial implementation of the control scheme, based upon results from long-term testing.

The test program will also assess the viability of re-injecting the collected sorbent/ash mixture from the ESP hoppers into the ESP, and impacts this will have on injection system operation, ESP operation and potential emission increases. The report will include and economic analysis identifying potential cost savings.

Based on input from the plant, the report will address modifications to existing plant equipment and develop a work scope document for the TOXECON II™ process. This may include modifications to the particulate collector, ash handling system, compressed air supply, electric power capacity, other plant auxiliary equipment, utilities, and other balance of plant engineering requirements.

Finally, the test program will develop a budget level cost estimate to implement the TOXECON II™ control technology. This will include capital cost estimates for mercury control process equipment as well as projected annual operating costs. Where possible, the report will include order-of-magnitude estimates for plant modifications and balance of plant items.

Task 10. Technology Transfer

The ultimate goal of technology transfer efforts is to make the program testing results available to the public as quickly, comprehensively and accurately as possible. To accomplish this goal, the program will make presentations at selected conferences, with DOE approval, to increase exposure of the test results and receive comments on the applicability of the technology to the industry.

Transferring the information generated during this program to the coal-fired utility industry is an important part of the program. Dr. Durham, who has led the technology transfer activities during the DOE Phase I and II programs, will lead this important activity. Technology transfer activities in the previous testing programs included participating in DOE/NETL-sponsored meetings, EPA Hg MACT Stakeholder meetings, presentations at more than 50 events or companies, hosting a project Web site for project team members and for presentation of project information, and publication of more than 100 technical papers.

ADA-ES will work with DOE/NETL to determine and support efforts for key meetings, presentations and publications. ADA-ES will also establish a Web site for the project and participants. ADA-ES has done this on other NETL projects with excellent results.

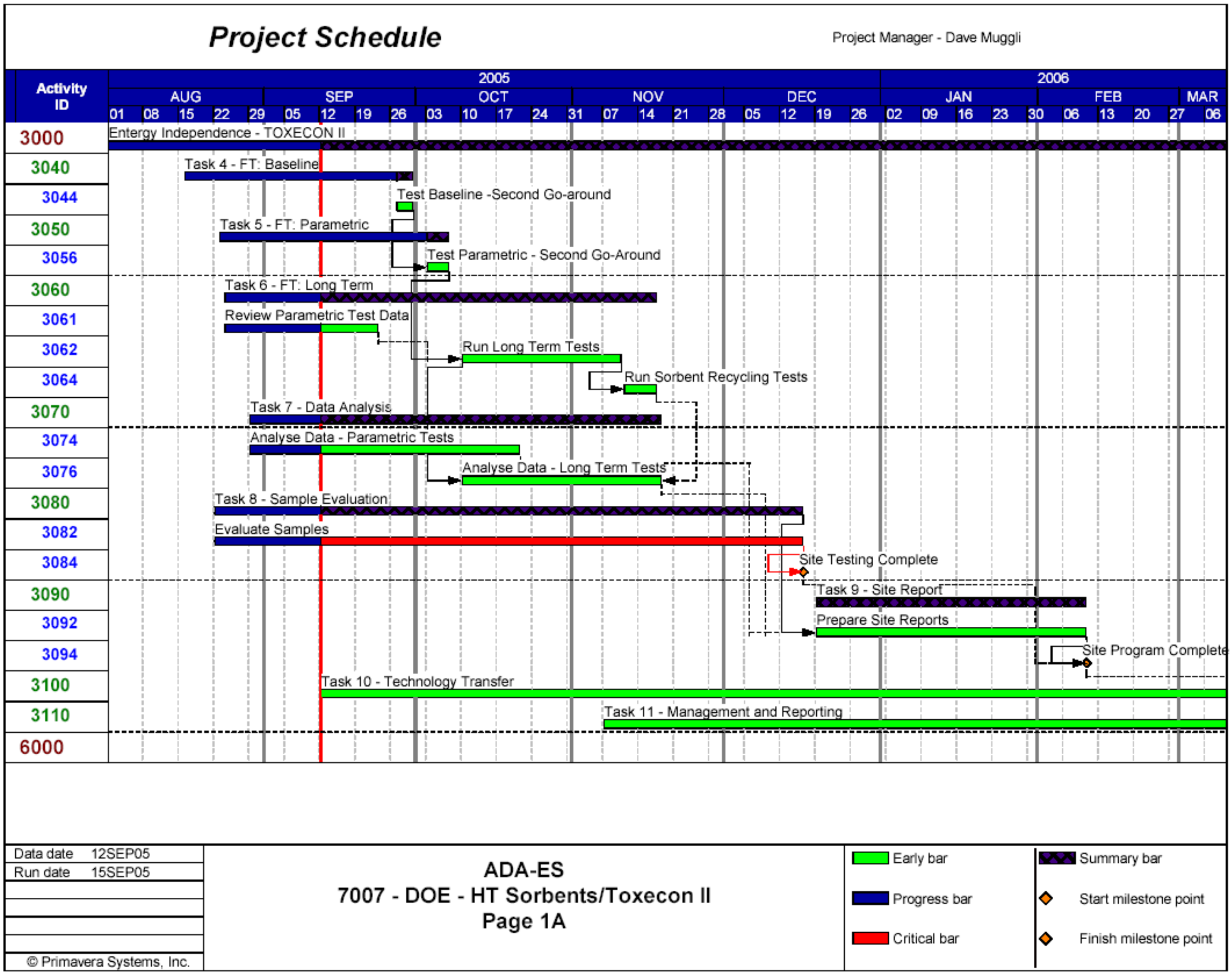
Task 11. Management and Reporting

This task includes the overall program management, and preparation of financial and administrative reports. This task will also include periodic meetings with DOE to discuss progress and obtain overall direction of the program from the DOE project manager.

Schedule

The current schedule for activities at Independence Station is shown in Figure 7.

Figure 7: Current Schedule for the Independence Test Program.



Test Plan

Key Personnel

Key personnel for the Independence tests are identified in Table 9.

Table 9. Key Project Personnel for Independence Mercury Field Evaluation.

Name	Company	Role	Phone #	E-Mail
Andrew O'Palko	DOE/NETL	Project Manager	304-285-4715	andrew.opalko@netl.doe.gov
Richard Roberts	Entergy	Entergy Technical Support	501-688-7068	rrobert@entergy.com
Dave Muggli	ADA-ES	Program Manager	303-339-8853	davem@adaes.com
Tom Campbell	ADA-ES	Site Project Manager	303-339-8864	tomc@adaes.com
Cody Wilson	ADA-ES	Site Project Engineer	303-339-8860	codyw@adaes.com
Mike Rees	Entergy	Superintendent	870-698-4573	mrees@entergy.com
Jerry Amrhein	ADA-ES	Hg Monitors	303-339-8841	jerrya@adaes.com
Steve Coker	Entergy	Sr. Engineer	870-698-4521	Scoker1@entergy.com
Kellee Cook	Entergy	Environmental Specialist	870-698-4517	Kcook2@entergy.con
Joe Hantz	Entergy	Fossil Environmental Support	281-297-3319	jhantz@entergy.com
Cam Martin	ADA-ES	Equipment Design	303-339-8849	camm@adaes.com
Richard Schlager	ADA-ES	Contracts	303-339-8855	Richards@adaes.com
Connie Senior	Reaction Engineering	Coal and Byproduct Issues	801-364-6925 ext 37	senior@reaction-eng.com
Michael Durham	ADA-ES	Technical Expert	303-734-1727	miked@adaes.com
Jean Bustard	ADA-ES	Technical Expert	303-734-1727	jeanb@adaes.com
Ramsay Chang	EPRI	Technical Expert	650-855-2535	rchang@epri.com

APPENDIX A2: Follow-On Test Plan—February 23, 2006

ELECTRIC POWER RESEARCH INSTITIUTE MERCURY FIELD EVALUATION

Evaluation of TOXECON II™ Sorbent Injection for Mercury Control at Entergy's Independence Steam Electric Station

Follow-On Test Plan dated February 23, 2006

For:
Entergy
EPRI

By:
ADA Environmental Solutions, Inc.
8100 SouthPark Way, Unit B
Littleton, CO 80120

February 23, 2006

Follow-on Test Plan for Entergy Independence Station
February 23, 2006

Based on discussions during the team conference call on Tuesday, February 21, 2006, the following topics were of interest or discussed during the course of the call:

1. Sorbent Injection in front of the ESP using currently available ADA-ES equipment and existing ports and access
2. Mass Emission testing to quantify any changes in mass emissions from TOXECON II™ – three runs of M17 tests at each test condition:
    a. Baseline (no sorbent injection),
    b. TOXECON II™ at 10lb/MMacf injection concentration,
    c. Pre-ESP injection at 10lb/MMacf injection concentration
3. CFD Modeling of the ESP, Injection System
4. If possible, increase LOI to observe influence on Hg removal rates
5. If possible, vary excess O_2 levels at low loads to observe influence on Hg removal rates
6. Test smaller particle size sorbent to observe influence on Hg removal rates (note – previous tests with smaller particle size sorbent has caused significant feeding problems using both the silo and Porta-Pacs)
7. Measure air flow within the test side of ESP B to assist in the accuracy of the CFD modeling
8. Investigate bringing a pilot wet scrubber on site to analyze speciation and removal effects
9. Creating an economic standard calculation to estimate the cost effectiveness of sorbent injection vs. baghouse prices

Given the current ACI inventory and available budget, ADA-ES is recommending the following tests be conducted in the next few weeks:

Sunday	Monday	Tuesday	Wed	Thursday	Friday	Saturday
Feb 26	27 Travel to site	28 System Start-up (analyzers, injection system, etc), no Injection	Mar 1 System Start-up, no injection M-17 Full Load	2 TOX-II injection @ 10 lb/MMacf	3 TOX-II injection @ 10lb/MMacf M17 Full Load	4 Shift Injection to in front of ESP @ 1lb/MMacf
Mar 5 Pre-ESP Injection @3lb/MMacf	6 Pre-ESP Injection @6lb/MMacf	7 Pre-ESP Injection @10lb/MMacf M17 Full Load	8 Shift to Dual TOX-II Injection (F5/F7) @6lb/MMacf Increase LOI	9 Dual TOX-II Injection @ 6lb/MMacf Decrease O2	10 Dual TOX-II Injection @ 6lb/MMacf ACI OFF use up PAC	11 System Shutdown

Upon completion of the above tests, ADA-ES will demobilize the site to the extent necessary to secure it for several months until the possible startup for a follow-up testing program. Also, ADA-ES will compile the information from the program for distribution to EPRI and the project team members.

Concurrent with the above test program, ADA-ES will pursue modeling of the existing injection grid to evaluate its possible impact on Hg removal with the TOXECON II process. Following this effort, ADA-ES can pursue installing an alternate design if the project budget can support it. Another potential activity is to perform an internal ESP flow profile measurement if the opportunity arises to help validate the ESP internal flow profile and the CFD modeling.

Due to budget limitations, the current planned efforts do not include the following:

- Testing with varying PAC particle size to observe the influence on Hg removal rates
- Bringing a pilot wet scrubber on site to analyze speciation and removal effects

APPENDIX A3: Independence Test Plan—December 29, 2006

DOE NATIONAL ENERGY TECHNOLOGY LABORATORY MERCURY FIELD EVALUATION

Evaluation of TOXECON II ™ Sorbent Injection for Mercury Control at Entergy's Independence Steam Electric Station

Test Plan

Prepared for:
Entergy
DOE NETL
EPRI

Prepared by:
ADA Environmental Solutions, Inc.
8100 SouthPark Way, Unit B
Littleton, CO 80120

December 29, 2006

Table of Contents

Project Objectives 1

Project Overview 1

Host Site Description 2

Field Testing 4

Baseline Testing 4

Parametric Testing 4

Long-Term Testing (Extended 30-day test) 5

Sample and Data Collection 7

Plant Operating Data 8

Sample and Data Analysis 9

Site Report and Technology Transfer 9

Design and Economics of TOXECON II 9

Schedule 10

Key Personnel 10

List of Tables and Figures

Table 1. Host Sites Participating in the Sorbent Injection Demonstration Project 1

Table 2. Independence Key Operating Parameters. 2

Figure 1. Sketch of West Half (Elevation View) of the ESP at Independence Unit 2....... 3

Figure 2: ESP Electrical Field and Ash Hopper Configuration. 3

Table 3. Proposed Test Matrix for Independence Unit 2 6

Table 4. Samples and Data Collection during Independence Testing 7

Table 5. Unit operating parameters requested for 15- minute logging during Independence 2 Sorbent Injection Testing. 8

Table 6. Key Project Personnel for Independence Plant Mercury Field Evaluation 10

Project Objectives

The objective of testing at Entergy's Independence Steam Electric Station (ISES) is to determine the cost and effects of sorbent injection using EPRI's TOXECON II ™ for mercury control. During this phase of testing, an evaluation of a redesigned injection grid and delivery system will be evaluated to determine if improved mercury removal at lower cost can be achieved compared to Independence results from 2005-2006. This evaluation will be conducted on $1/16^{th}$ of the 842 MW, Unit 2 flue gas stream.

Project Overview

This test is part of an overall program funded by the Department of Energy's National Energy Technology Laboratory (DOE/NETL) and industry partners to obtain the necessary information to assess the feasibility and costs of controlling mercury from coal-fired utility plants using either high temperature sorbents or EPRI's TOXECON II™ process. Host sites of this program are shown in Table 1. These host sites reflect a combination of coals and existing air pollution control configurations.

Table 1. Host Sites Participating in the Sorbent Injection Demonstration Project

	Coal / Options	APC	Capacity (MW) / Test Portion	Current Hg Removal (%)
Entergy's **Independence Station Unit 2**	PRB	Cold-Side ESP	842/53	10-20%
MidAmerican's **Louisa Station Unit 1**	PRB	Hot-Side ESP	700/350	<10%
MidAmerican's **Council Bluffs Station Unit 2**	PRB	Hot-Side ESP	88/88	<10% (Estimated)

Previous mercury control evaluations at ISES Unit 2 indicated that, although significant mercury control could be achieved by using the TOXECON II™ design, the sorbent concentration required was higher than expected. Through EPRI funding, the original lance design was modeled and results confirmed significant sorbent mal-distribution. Lances have been redesigned to improve the sorbent distribution. A lance grid was installed at Independence in December 2006 to treat $1/16^{th}$ of the Unit 2 flue gas flow. This test plan describes tests planed to characterize the performance of the re-designed lances.

Host Site Description

The Independence Steam Electric Station is located in Independence County, Arkansas near the town of Newark.

Unit 2 is an 842-MW (gross) pulverized coal, electric generating unit with Lungstrum regenerative air preheaters that burns PRB coal. Key operating parameters for Unit 2 are included in Table 2.

Table 2. Independence Key Operating Parameters.

Unit	2
Size (MW)	842
Test Portion (MWe)	106
Flue Gas Flow acfm	3,200,000
Coal	PRB
Heating Value (as received)	8,700
Sulfur (% by weight)	0.32
Chlorine (%)	~0.01
Mercury (μg/g)	0.04
Particulate Control	Cold-Side ESP SCA = 542 ft^2/kacfm
Sulfur Control	Compliance Coal
Air Pre-Heater	Regenerative
Ash Reuse	Sold

Independence Unit 2 is equipped with four ESPs in a piggyback configuration, with two boxes on top and two boxes on the bottom, operating in parallel for particulate removal. A sketch of one-half of the Unit 2 flue gas path showing two injection locations that were utilized during the previous testing is presented in Figure 1. For the objectives of this test period only the injection location identified as “1” will be utilized.

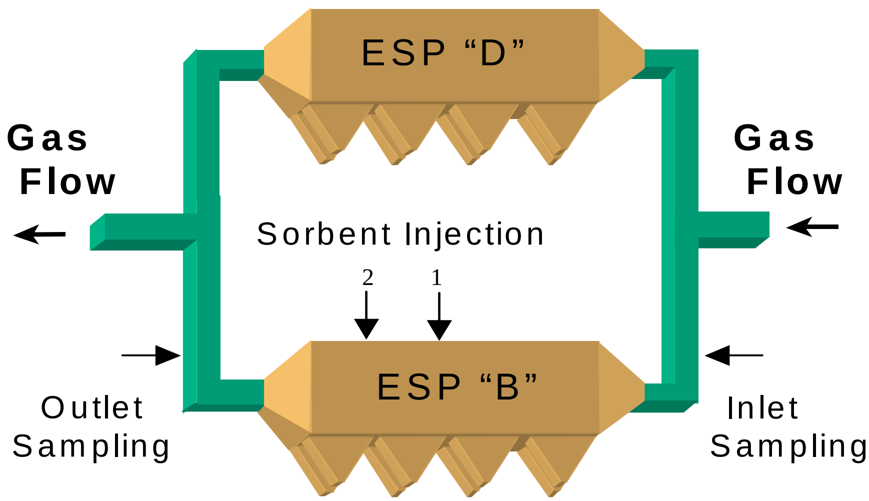


Figure 1. Sketch of West Half (Elevation View) of the ESP at Independence Unit 2.

Each ESP has eight TR sets configured as shown in Figure 3. TR sets 1, 3, 5 and 7. Injection lances are installed upstream of electrical field 5. The ash collection hopper designations are shown to the right in Figure 2. Eight injection lances are installed upstream of hoppers 31 and 41.

Inlet → ***Outlet***

1	3	5	7
2	4	6	8

ESP Electrical Fields

Inlet → ***Outlet***

11	21	31	41
12	22	32	42
13	23	33	43
14	24	34	44

ESP Ash Hoppers

Figure 2: ESP Electrical Field and Ash Hopper Configuration.

Two mercury Semi-Continuous Emissions Monitors (SCEMs) will be used during the test period. Extraction locations will be upstream and downstream of the treated ESP. The downstream location will be in-line with the injection lances to assure representative outlet measurements.

Field Testing

Field-testing is planned in three phases: baseline, parametric, and long-term testing. These are described below. Additional tasks associated with each testing phase are sample and data collection, sample and data analysis, economic analysis of the technology based upon the test results, and reporting. These tasks are described in separate sections.

Baseline Testing

The baseline test period is split. One day of baseline testing (no sorbent injection) is scheduled prior to parametric testing, after the SCEMs are brought on-line, to assure all measurement equipment is in good working order and to characterize native mercury capture across the ESP. Unit operation will be set to include conditions expected during the parametric tests. Manual testing will include modified Appendix K, Sorbent Trap Method (STM), mercury measurements. An extended baseline test period is scheduled before the long-term carbon injection test. During this baseline testing, Method 5/202 particulate/condensable tests will be conducted at the stack to establish and characterize baseline particulate emissions for the entire unit. Particulate testing at the stack will include one six hour test each day for five consecutive days. Extended tests at the stack are scheduled to minimize run-to-run variations often observed for shorter sampling runs. During these tests, two Electrostatic Precipitator (ESP) conditions will be explored: the first during the one day Baseline period with normal ESP operating conditions - the Precipitator Optimization System (POS) controlling ESP power levels; and the second during the longer Baseline period with the transformer rectifier (TR) set B-5 and B-7 at 100% operating power. The TR set power levels are defined at 100% for prevention of back corona, not maximum output. The ESP rapping frequency will be set to once every four hours, standard operating conditions for the plant. The plant will shift the soot blowing system into the P-4 control scheme to minimize variation in soot blowing artifacts during Method 5/202 testing. STMs will also be conducted during the extended baseline test. Continuous mercury measurements will be made with the SCEMs installed upstream and downstream of the ESP and in line with the injection grid.

Parametric Testing

A new regenerative blower for the carbon injection system has been delivered to ISES and will be installed prior to parametric testing. Following initial baseline testing, 4-days of parametric testing are planned as shown in the test matrix (Table 3). The test matrix was designed to evaluate the effectiveness of the new sorbent injection grid, to determine the optimal carrier air flow for the current grid design, and characterize mercury removal as a function of injection concentration at high and low boiler load. During parametric tests, the ESP rapping frequency will be set to once every four hours, standard operating procedure for the plant. The target ESP operation for TR sets B-5 was 100% and B-7 was 50%. STMs will be conducted during one test condition. Continuous mercury measurements will be made with the SCEMs installed upstream and downstream of the ESP.

After parametric testing is completed, the project team will evaluate the data collected to determine the optimum long-term testing conditions.

Long-Term Testing (Extended 30-day test)

An "extended" 30-day continuous injection test will be conducted at the "optimum" settings as determined in the parametric tests and approved by DOE, EPRI, and Entergy/Independence. It is the intent of DOE that these settings represent the most cost effective condition for mercury removal. The goal of this task is to obtain operational data on removal efficiency over an extended period to indicate the effects on the particulate control device, effects on byproducts (ash), and impacts to the balance of plant equipment to begin to evaluate the viability of the process and determine the process economics.

During this period, Method 5/202 particulate/condensable tests will be conducted to characterize particulate emissions during carbon injection. Since only one 1/16th of the flue gas is being treated with carbon, two test locations will be utilized to maximize the analysis. To correlate with Baseline testing, two days of tests will be conducted at the stack to determine overall impacts on the plant. The Method 5/202 particulate sampling will then be moved to the ESP outlet for 5 days. Three simultaneous 6-hour Method 5/202 samples will be collected per day for five days: one upstream of the test-side ESP, one downstream of the test side of the ESP downstream of the injection point, and one downstream of the control side of the ESP. The purpose of extended particulate sampling runs is to minimize run-to-run variations often encountered during shorter sampling runs. During M5/202 testing, CPM measurements will be taken across the outlet of the test-side ESP and the control-side ESP.

During the particulate testing, the ESP outlet field rapping frequency will be established at 4 hours for the days of stack testing and one day of ESP outlet testing. The outlet field rap cycle will then be changed to once per hour. The test side outlet TR set power levels will be in manual at 100%. Based on results during testing, TR set B-7 may be shifted to 50% power levels. During these M5/202 test sequences, the soot blowing schedule will conform to the P-4 scheme to allow data correlation with Baseline measurements. STMs will also be conducted during this phase of testing. Continuous mercury measurements will be made with the SCEMs installed upstream and downstream of the ESP.

Table 3. Proposed Test Matrix for Independence Unit 2

Test Description	Date	Test Day	Test Dur. (hrs)	Inj. Conc. (lb/MMacf)	Blower Setting	Boiler Load	Special
Blower and SCEM checkout	Jan 10 - 14, 2007	0		NA	OFF	Any	
Baseline	Mon 1/15/07	1	24	0	OFF	Any	STM
Parametric	Tue 1/16/07	2	3	1	Model	Full[1]	
			2	1	Model -	Full[1]	
			2	1	Model +	Full[1]	
			8	1	Best (A)	Low[1]	
	Wed 1/17/07	3	3	1	A	Full[1]	
			3 +	3	A	Full[1]	STM
			8	3	A	Low[1]	
	Thu 1/18/07	4	3	3	A	Full[1]	
			3+	6	A	Full[1]	
			8	6	A	Low[1]	
	Fri 1/19/07	Contingency					
	1/20/07 – 1/28/07	*Break to review data. Move forward with Long-Term if >80% removal at ≤ 3 lb/Macf*					
Baseline	1/29/07 – 2/1/07	BL 1-5	5 days	0	OFF	Full[1] for PM	PM
Long-Term Week 1	2/2/07 – 2/9/07	LT 1-7	7 days	TBD	A	Full[1] for STMs	STM
Long-Term Week 2	2/10/07 – 2/16/07	LT 8-14	7 days	TBD	A	Full[1] for PM	PM
Long-Term Week 3	2/17/07 – 2/23/07	LT 15-21	7 days	TBD	A	Full[1] for STMs	STM
Long-Term Week 4	2/24/07 – 3/4/07	LT 22-30	9 days	TBD	A		

Notes:

1. For parametric and long term tests noted, place ESP in 1 hour rap cycle. Field 5 TR sets to manual full power (100%). Field 7 TR sets to manual 100%.
2. Full Load = 842MW ± 5%
3. Sorbent injection will be stopped if the ESP spark rate or Unit 2 opacity exceeds levels determined by plant personnel at beginning of test week.

Sample and Data Collection

During every test day, the ADA-ES Site Manager will be on site or on call. The ADA-ES Site Manager will manage coordination on site between all ADA-ES activities and the plant staff. Plant staff will be collecting coal and ash samples and providing unit operating data for use in evaluating the mercury program results. Samples and data that will be collected during testing are summarized in Table 4.

Table 4. Samples and Data Collection during Independence Testing

Parameter Sample/signal/test	**Baseline**	**Parametric**	**Long-Term**
Coal daily composite*	Yes	Yes	Yes
Fly ash daily hopper samples: **	Yes	No	Yes
Unit operating data: boiler load, ESP operation, CEMS Data, etc. (listed separately in Table 5)	Yes	Yes	Yes
Mercury (total) monitors at ESP inlet and ESP outlet – SCEMs	Yes	Yes	Yes
Mercury (total) STM at inlet/outlet	Yes(1 set)	Yes(1 set)	Yes(1 set)
Particulate, M5/202	Yes	No	Yes
Sorbent Injection Rate, lb/min	No	Yes	Yes

*** Coal Sampling**

Coal sampling will be collected and will represent the coal as an "as burnt" sample that can be correlated to the operating conditions and data taken during the test program. All samples will be collected in labeled 1-Liter containers provided by ADA-ES. One sample will be collected each day. ADA-ES personnel will take custody of the samples and composite them on site for shipment and analysis.

**** Fly Ash Sampling**

Ash will be collected from two test hoppers (31 and 41) and two control hoppers (34 and 44). The hoppers should be emptied at about 1200 hours. Ash sampling will then occur at approximately 1100 hours. The schedule for hopper bypass is at 1200, all hoppers in bypass will be emptied. Hoppers 3-1, 3-2, 3-4 and 4-1, 4-2, and 4-4 will then be placed in bypass until the next day. Hopper 2-1 and 2-2 will be isolated at 0800 until 1200 to allow sufficient ash to collect.

Operations personnel or ADA-ES personnel will collect each ½-1L fly ash sample in a separate, labeled 1-L containers (provided by ADA-ES). Three, 5-gallon buckets of ash from the baseline testing and Long-Term will also be collected for DOE.

Plant Operating Data

The ADA-ES Site Manager will work closely with plant operators to monitor key plant operating parameters in real-time during testing. In addition, ADA-ES requests unit-operating data in electronic form on a fifteen-minute average basis. The list of requested plant data is provided in Table 5. If possible, it is useful if plant-operating data can be provided daily. If at any time the performance of the existing pollution control equipment or outlet emissions exceed acceptable operating limits, testing will be halted. Acceptable limits will be discussed and agreed upon prior to beginning injection.

Table 5. Unit operating parameters requested for 15- minute logging during Independence 2 Sorbent Injection Testing.

Parameter	**Unit(s)**
Load	MW, gross and net
Heat Rate	Btu/MW-hr
ID Fan	Amps
Boiler O_2	%, wet
Duct O_2	%, wet
Mill Fuel Flow	klb/hr
Boiler Air Flow	%
Main Steam Flow	klb/hr
AH Differential Pressure	in H_20
AH Gas Temperatures	F
AH Air Temperatures	F
SOFA position	%
CCOFA position	%
SO_3 Injection Rate	%, lb/hr
Sulfur burner DT	F
Main sootblower header steam flow	klb/hr
Ambient T	F
Barometric P	in Hg
Stack T, Flow, Velocity	F, lb/hr, ft/s
NO_x	ppm, lb/MMBtu
SO_2	ppm, lb/MMBtu
CO_2	%, wet
Opacity	%, 6-minute
TR Primary	V, A
TR Secondary	kV, mA
TR Spark Rate	spark/min

Miscellaneous notes daily:

- Equipment out of service, failures or upsets, note time and remedy
- Fuel type fired and source (train or coal pile)
- Soot-blowing or water cannon schedule

Sample and Data Analysis

Data collection and analysis for this program is designed to measure the effect of sorbent injection on mercury control and the impact on the existing pollution control equipment. The mercury levels and plant operation will be characterized with and without sorbent injection and the long-term evaluation to identify effects that may not be immediate.

Select coal and ash samples will be chosen by the test team for analysis. Ultimate and proximate analyses will be performed and mercury, chlorine, and sulfur levels will be determined for the coal samples. The ash will be analyzed for mercury. Leaching tests will be conducted to determine if the mercury is stable on the ash. Ash samples will also be sent to DOE for additional analyses on a separate program.

Site Report and Technology Transfer

A site report will be prepared documenting measurements, test procedures, analyses, and results. This report is intended to be a stand-alone document providing a comprehensive review of the tests and results. The report will include details from testing throughout this DOE program (2005 – 2007).

Design and Economics of TOXECON II

One aspect of the site report is an economic analysis. After completion of field testing and analysis of the data, the requirements and costs for full-scale permanent commercial implementation of the selected mercury control technology will be determined.

The ADA-ES program team will meet with the host utility plant and engineering personnel to develop plant-specific design criteria. Process equipment will be sized and designed based on test results and the plant-specific requirements (reagent storage capacity, plant arrangement, retrofit issues, winterization, controls interface, etc.). A conceptual design document will be developed. Sorbent type and sources will be evaluated to determine the most cost-effective reagent(s) for the site.

Modifications to existing plant equipment will be determined and a work scope document will be developed based on input from the plant. This may include modifications to the particulate collector, ash handling system, compressed air supply, electric power capacity, other plant auxiliary equipment, utilities, and other balance of plant engineering requirements.

Finally, a budget cost estimate will be developed to implement the control technology. This will include capital cost estimates for mercury control process equipment as well as projected annual operating costs. When possible, order-of-magnitude estimates will be included for plant modifications and balance of plant items.

Schedule

The tentative schedule for site activities at Independence Power Plant is include in the test matrix. A draft of the comprehensive report will be issued within 8 weeks of completing site activities.

Key Personnel

Key personnel for testing at Labadie Plant are identified below in Table 6.

Table 6. Key Project Personnel for Independence Plant Mercury Field Evaluation

Name	Company	Role	Phone #	E-Mail
Andrew O'Palko	DOE/NETL	Project Manager	304-285-4715	andrew.opalko@netl.doe.gov
Richard Roberts	Entergy	Entergy Technical Support	501-688-7068	rrobert@entergy.com
Sharon Sjostrom	ADA-ES	ADA-ES Project Manager	303-339-8856	sharons@adaes.com 303-919-8538
Brian Donnelly	ADA-ES	ADA-ES Site Manager	303-339-8865	briand@adaes.com 303-921-8153
Tom Campbell	ADA-ES	Senior Project Engineer	303-339-8864	tomc@adaes.com 303-981-7287
David Graham	ADA-ES	Senior Project Engineer	303-339-8845	davidd@adaes.com 303-520-9058
Todd Bradberry*	Entergy	Engineer	870-698-4581	BBRADBE@entergy.com
Steve Coker	Entergy	Sr. Engineer	870-698-4521	Scoker1@entergy.com
Kellee Fletcher	Entergy	Environmental Specialist	870-698-4517	Kfletch@entergy.con
Joe Hantz	Entergy	Fossil Env. Support	281-297-3319	jhantz@entergy.com
Connie Senior	Reaction Engineering	Coal and Byproduct Issues	801-364-6925 ext 37	senior@reaction-eng.com
Ramsay Chang	EPRI	Technical Expert	650-855-2535	rchang@epri.com

* Shipping to Independence will be coordinated through Todd Bradberry.

APPENDIX A4: Extended Test Matrix

Date	Day	Sorbent Injection	SCEM Online	Field 5 Injection	Field 7 Injection	Opacity Testing	Removal % Testing	Sorbent Screening	Porta-PAC: Alt Sorbent
15-Nov	Tuesday								
16-Nov	Wednesday	x	x	x					
17-Nov	Thursday	x	x	x		x			
18-Nov	Friday	x	x	x		x			
19-Nov	Saturday	x	x	x					
20-Nov	Sunday	x	x	x					
21-Nov	Monday	x	x	x					
22-Nov	Tuesday	x		x					
23-Nov	Wednesday	x		x					
24-Nov	Thursday	x		x					
25-Nov	Friday	x		x					
26-Nov	Saturday	x		x					
27-Nov	Sunday	x		x					
28-Nov	Monday	x		x					
29-Nov	Tuesday	x	x	x		x	x	x	
30-Nov	Wednesday	x	x	x		x	x	x	
1-Dec	Thursday	x	x		x	x	x	x	
2-Dec	Friday	x	x		x	x	x	x	
3-Dec	Saturday	x	x		x		x		
4-Dec	Sunday	x	x		x		x		
5-Dec	Monday	x	x		x	x	x		
6-Dec	Tuesday	x	x		x	x	x		
7-Dec	Wednesday	x	x	x	x	x	x		
8-Dec	Thursday	x	x	x		x	x		
9-Dec	Friday	x	x	x		x	x		
10-Dec	Saturday	x	x	x					
11-Dec	Sunday	x	x	x					
12-Dec	Monday	x	x	x					
13-Dec	Tuesday	x	x	x					
14-Dec	Wednesday	x	x	x					
15-Dec	Thursday	x	x	x					
16-Dec	Friday	x	x	x					
17-Dec	Saturday	x	x	x					
18-Dec	Sunday	x	x	x					
19-Dec	Monday	x	x	x					
20-Dec	Tuesday	x	x	x					
21-Dec	Wednesday	x	x	x					
22-Dec	Thursday	x		x					
23-Dec	Friday	x		x					
24-Dec	Saturday	x		x					
25-Dec	Sunday	x		x					
26-Dec	Monday	x		x					
27-Dec	Tuesday	x		x					
28-Dec	Wednesday	x		x					
29-Dec	Thursday	x		x					
30-Dec	Friday	x		x					
31-Dec	Saturday	x		x					
1-Jan	Sunday	x		x					
2-Jan	Monday	x		x					

3-Jan	Tuesday	x	x	x			
4-Jan	Wednesday	x	x	x			
5-Jan	Thursday	x	x	x			
6-Jan	Friday	x	x	x			
7-Jan	Saturday	x	x	x			
8-Jan	Sunday	x	x	x			
9-Jan	Monday	x	x	x	x	x	
10-Jan	Tuesday	x	x	x	x	x	
11-Jan	Wednesday	x	x	x	x	x	
12-Jan	Thursday	x	x	x	x	x	
13-Jan	Friday	x	x	x	x	x	
14-Jan	Saturday	x	x	x			
15-Jan	Sunday	x	x	x			
16-Jan	Monday	x	x	x		x	
17-Jan	Tuesday	x	x	x		x	x
18-Jan	Wednesday	x	x	x		x	x
19-Jan	Thursday	x	x	x		x	x
20-Jan	Friday	x	x	x		x	
21-Jan	Saturday	x	x	x			
22-Jan	Sunday	x	x	x			
23-Jan	Monday	x	x	x		x	
24-Jan	Tuesday	x	x	x		x	x
25-Jan	Wednesday	x	x	x		x	x
26-Jan	Thursday	x	x	x		x	x
27-Jan	Friday	x	x	x		x	
28-Jan	Saturday	x	x	x			
29-Jan	Sunday	x	x	x			
30-Jan	Monday	x	x	x			
31-Jan	Tuesday						

APPENDIX B:

Equipment Descriptions

Mercury Monitors

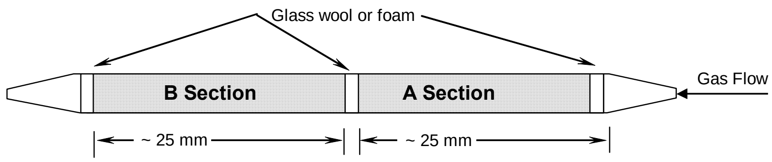
Vapor-Phase Mercury Emissions Using Sorbent Trap Method (STM)

This non-isokinetic test method samples flue gas while minimizing particulate capture, and provides total vapor-phase mercury emissions. The dry sorbent trap method was proposed in the Utility Mercury Reduction Rule (FR January 30, 2004) as a draft EPA test method, *Method 324 Determination of Vapor Phase Flue Gas Mercury Emissions from Stationary Sources Using Dry Sorbent Trap Sampling.* The method was proposed in the Utility Mercury Reduction Rule either for application as a reference method test, or for continuous compliance measurement for mercury. ADA-ES has used the method in the field since the early 1990s, and conducted the validation testing for Method 324, in which it compared favorably with the Ontario Hydro Method. The procedures used during the Independence tests were consistent with the procedures used during validation testing of the new Method.

In the Clean Air Mercury Rule (CAMR) signed by the EPA Administrator on March 15, 2005, the proposed Method 324 was revised and renamed as 40 CFR Part 75 Appendix K. The revised and renamed method will be an option for some sources for continuous compliance measurements for mercury. The method described in Appendix K has many rigorous quality control requirements that are in excess of what is necessary for the Big Brown tests. However, the principles of the method described in 40 CFR Part 75 Appendix K will be applied in this test program and will be referred to as the sorbent trap method (STM). The detailed procedures to be followed are summarized here.

This mercury measurement method extracts a known volume of flue gas from a duct through a dry sorbent trap (containing a specially treated form of activated carbon) as a single-point sample, with a nominal flow rate of about 400 cc/min at the gas meter. The dry sorbent trap, which is in the flue gas stream during testing, represents the entire mercury sample. Each trap is recovered in the field and shipped to a specialized lab such as Frontier GeoSciences, Inc. for analysis. Each trap is acid leached and the resulting leachate is analyzed for mercury using cold vapor atomic fluorescence spectrometry. Samples can be collected over time periods ranging from less than an hour to weeks in duration. The test result provides a time-averaged total vapor-phase mercury measurement of the flue gas stream.

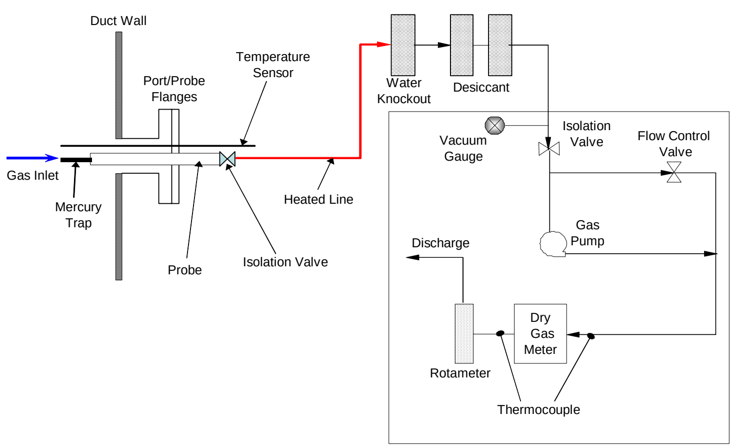
STM sampling collects paired samples as a quality control measure. The analysis results of the paired sample trains are compared and are typically in agreement within 5–20% relative percent difference (RPD) or about 1 lb/TBtu. Another built-in quality assurance



measure is achieved through the analysis of two trap sections in series. Each trap has two separate mercury sorbent sections, as shown in the figure below, and the "B" section is analyzed to evaluate whether any mercury breakthrough occurred. Low B section mercury, in conjunction with a field blank trap, is used to confirm overall sample handling quality.

The sample train is fairly simple, as shown below. Major components are a dry sorbent trap mounted directly on the end of a probe (usually heated), a moisture knockout outside the duct, and a sampling console that controls the sampling rate and meters the flue gas, as well as recording data in a data logger. Key temperatures, sampling volume, and barometric pressure are recorded on field sampling data sheets and/or by a data logger for each sample run.

The STM directly measures mercury concentration in units of µg/dNm^3. Using stack gas flow rate and gaseous data from the plant's CEMS and coal Ultimate Analysis (or EPA Method 19 F-Factors if Ultimate Analysis is unavailable), results can be calculated and reported in lb/TBtu.



Sampling Console

APPENDIX C:

Field Test Logs

APPENDIX C1: Independence Test Log—November 15, 2005

Entergy Independence Unit 2
DOE TOXECON™ II Mercury Control Evaluation

8/14/05
0800 – EZ, TC, BD on site.
0900 – Calibrate system.
1000 – Begin work on TEOM system. Set up but unable to install in duct, bendable probe will not bend down due to obstruction.
Test hopper sample system, take 5 gal sample for Lynn Birkett, DOE.
1800 – Depart site.

8/15/05
0800 – EZ on site for system calibration.
0830 – TC, BD on site.
0930 – After calibrating system, begin Baseline data collection.
1000 – Plant is at full load.
1100 – Begin sample routine.
1900 – Release plant to load follow.

8/16/05
0800 – EZ on site for system calibration.
0855 – Plant begins to raise load, stabilizes at 1000.
0930 – CL, TC, BH on site for testing.
1000 – METCO on site. Waiting on scaffolding additions.
1030 – Remove TEOM probe per METCO request. Modified TEOM bearing mount to allow operation in duct. Unable to test in duct.
1400 – Scaffolders come on site to modify scaffolding set up for METCO. Complete at 1700. METCO will wait until tomorrow for testing.
1930 – Release plant to load follow.

8/17/05
0800 – EZ on site for system calibration
0830 – CL on site to assist with off loading Porta-PAC and 14 supersacks of Hg, Hg-LH, E-10 and E-11.
0925 – Plant begins raising load to 840 MW. Completes at 1010.
0945 – BH and TC on site for start of testing for the day
1000 – Coal sample from north conveyor
1230 – Started 1st run of Ontario Hydro. Perform 324.
1300 – Talk with Mike Rees. Field 7 (outlet field on test side of ESP) is down and has been down for at least a week. Initial report is a hard ground but testing finds it comes up to power but loses power due to spark rate, runs about one hour. Isolate problem to rappers not functioning on field 7. Bring rappers on line but improvement is limited. Inform team, schedule meeting for Thursday.

1700 – Complete run 1 of Ontario Hydro. Test was long and slow, METCO thinks data will be good.
1845 – Start run 2 of Ontario Hydro. Perform 324 test.
2130 – Finish run 2 of Ontario Hydro.
2200 – Release plant to load follow.

8/18/05
1000 – CW, TC, EZ, CL, BH onsite.
1046 – After reviewing the ESP data for the past couple months, it was determined that field 7 has been out of operation since July 20. The plant is working to restore this field so that parametric testing can continue as planned.
1100 – Started 3rd run of source testing (OH, M5, M26a).
1140 – Reset CPM5000 for stack test calibration.
1415 – Complete 3rd run of Ontario Hydro.
1445 – Completed CPM5000 stack test calibration. Test side window value was .76%, control side window value is .81%.
1500 – Discussion of inlet and outlet Hg data on SCEM analyzers continues. Inlet numbers appear to run higher at low loads and as load is increased, off gas through the first several hours of testing. Then outlet continues to decline until lower than inlet. Need to do some data averaging to get a grip on data and ensure analyzers are working properly.
1600 – Set up TEOM7000 and power up.
1700 – Change RSView program.
1715 – Release plant to load follow.
1739 – Change RSLogix
1745 – Depart.

8/19/05
0800 – EZ, BH onsite. Chiller condensate pump at outlet sample port has quit, analyzer (EMC2) has taken on water.
0930 – TC, CW onsite.
1000 – Collected coal sample from north conveyor.
1300 – EMC2 has been overhauled, new gold, new detector tube, one of the solenoid valves replaced, sample lines flushed with HnO3 and water. Pump on chiller has been reconditioned and is working properly.
1600 – Complete ash sampling, Hoppers 4-2 and 3-2 are empty, no sample collected. Sampled hoppers 2-2, 1-2 & 1-3.
1630 – Started FAS.
1730 – Stopped FAS.
1800 – Stopped working.

8/20/05
0800 – EZ, BH, and CW onsite.
0810 – EMC2's computer locked up over night. The analyzer will not reboot. Working on downloading the collected data since yesterday afternoon until when the analyzer froze up. After that the analyzer hard drive will be formatted and the control files reloaded.
0912 – Collected coal sample.

0939 – Tested the Porta-PAC motor rotation and feeder operation. The system is working fine.
0950 – EMC-2 is back online and sampling. Deletion of the data files on the analyzer hard drive solved problem.
1025 – Conducted TEOM 6 point velocity traverse.
1115 – Started TEOM continuous test.
1500 – Stopped TEOM continuous test.
1549 – EMC analyzers are working great. Inlet Hg concentration is greater than that outlet. This is not what we have been seeing the past couple days at this time.

8/21/05
0830 – EZ, BH, and CW onsite.
0845 – EMC2 Hg analyzer froze up over night again. It appears this happened at around 1740. Removed all files from the analyzer computer and re-installed software. Data files were downloaded to the analyzer computer.
1045 – Started TEOM continuous particulate run at ESP outlet.
1130 – Started FAS at ESP inlet.
1230 – Stopped FAS
1230 – Inlet and outlet analyzers are finally operating. Outlet was flooded at one point.
1320 – Continue to struggle with Hg analyzers. The outlet calibration is drifting quickly. Currently the outlet is reading higher than the inlet by 2 ug/dNm.
1410 – Recalibrated the outlet Hg analyzer. This made the outlet Hg concentration decrease below the inlet Hg concentration by 1 ug/dNm.
1425 – Stopped TEOM continuous particulate run at ESP outlet.

8/22/05
0800 – EZ, BH onsite
0825 – CW Onsite
0830 – Inlet and outlet Hg analyzers are working fine. Outlet concentration is currently higher than the inlet by 0.5 ug/dNm.
1100 – Calibrated Porta-PAC. New maximum feedrate at 2000 rpm is 760.
1120 – Started DARCO Hg injection at 3 lbs/MMacf (78 lbs/hr) in front of field 5.
1140 – Inlet Hg is stable at 7.8 ug/dNm. Outlet just before sorbent injection started was at 9.2 ug/dNm. After started sorbent injection, the outlet Hg dropped to 3.3 ug/dNm, representing about a 60% incremental decrease in Hg emissions. Removal from inlet to outlet is 58%. Outlet analyzer was still higher than the inlet analyzer by 1 ug/dNm at the start of sorbent injection.
1220 – Inlet Hg T = 6.94 (7.56) ug/Nm3; Outlet Hg T = 2.34 (2.62) ug/Nm3.
1431 – Collected FAS sample from ESP inlet.
1510 – Increased ACI to 5 lbs/MMacf (156 lbs/MMacf) in front of field 5. Outlet Hg is stable at 1.7 ug/dNm prior to increasing sorbent feedrate.
1642 – Collected ash samples. Samples from row three are very dark from row 3 hoppers.
1751 – Stopped ACI injection.
1800 – Noticed increase in outlet particulate as measured by CPM5000 on test side during sorbent injection. Step changes observed at both injection rate changes.
1900 – Left Site

8/23/05

0800 – CL, BH, CW onsite
0930 – Loaded super sack of DARCO Hg-LH onto the Porta-PAC
1100 – Calibrated Porta-PAC feeder. New maximum feedrate is 875 lbs/hr.
1130 – The outlet analyzer is reading 5.6 ug/dNm total Hg with less than 1 ug/dNm being elemental. Inlet is reading 6.5 ug/dNm total and 5.5 ug/dNm elemental. Either a lot of the Hg is being oxidized across the ESP or something is wrong with the elemental sample train on the outlet.
1226 – Started ACI at 26 lbs/hr in front of field 5.
1325 – After starting DARCO Hg-LH sorbent injection, outlet Hg concentration has decreased from approximately 6.5 ug/dNm to 2.7 ug/dNM.
1430 – DCM on site
1525 – Collected ESP hopper ash samples.
1545 – Collected FAS sample.
1629 – Increased DARCO Hg-LH injection rate to 78 lbs/hr in front of field 5.
1721 – Ran TEOM particulate monitor during 78 lbs/hr injection rate.
1929 – Increase DARCO Hg-LH injection rate to 156 lbs/hr in front of field 5.
2000 – Ran TEOM particulate monitor during 156 lbs/hr rate.
2010 – No noticeable increase in outlet particulate emissions as measured by CPM5000.
2227 – Increased DARCO Hg-LH injection rate to 200 lbs/hr in front of field 5.

8/24/05

0800 – CL, BH, CW, DCM onsite
1000 – Loaded super sack of DARCO e-10 onto Porta-PAC.
1020 – Changed "B" factor in CPM calibration equation from 1.0 to 20.0 for both CPMs
1120 – Started TEOM particulate monitor.
1138 – Calibrated Porta-PAC with DARCO e-10 sorbent. New maximum feedrate at 2000 rpm is 760 lbs/hr.
1228 – Started DARCO E10 sorbent injection at 78 lbs/hr in front of field 5.
1530 – Collected ESP hopper ash samples.
1542 – Started FAS at ESP inlet.
1547 – Increased DARCO E10 injection rate to 156 lbs/hr in front of field 5.
1440 – Ran STMs at the ESP inlet and outlet.
1920 – Stopped TEOM particulate monitor.
1943 – Stopped DARCO E10 injection.
2030 – Left Site

8/25/05

0800 – CL, BH, CW, DCM onsite
1000 – Sample North Coal Conveyor
1025 – Started TEOM at ESP outlet.
1045 – Calibrated Porta-PAC with DARCO E-11. New Maximum feedrate at 2000 rpm is 800 lbs/hr.
1104 – Started DARCO E11 injection at 78 lbs/hr in front of field 5.
1210 – Started STM tests at ESP inlet. This will be a port traverse at both locations.
1553 – Finished 4th sorbent trap at ESP inlet and outlet

1613 – Increased DARCO E11 injection rate to 156 lbs/hr.
2001 – Stopped sorbent injection.
2200 – Left site.

9/7/05
Travel Denver, CO to Newark, AR.
1500 – TC & BH arrive on site. Set up and leak checked the TEOM and downloaded CPM data. TEOM and CPM do not appear to work off same computer.
1800 – Depart site.

9/8/05
0800 – Arrive on site.
0930 – TEOM acting up. Get it working properly at 12 pm.
1100 – Begin injecting Hg-LH at 3 lb/MMacf in front of field 5 with plant at full load at 1015.
1500 – Increase injection rate to 6 lb/MMacf. Two spikes in CPM and TEOM data during this period. Looks like it was related to rapping, but unable to determine source exactly.
1900 – Injection stops when super-sack depletes. Gather data.
2000 – Depart site.

9/9/05
0830 – Arrive on site.
0900 – Load DARCO Hg on Porta-PAC
0930 – Change filter on TEOM and start test
1025 – Calibrate Porta-PAC for 76 and 156 pph, start feeding DARCO Hg at 3 lb/MMacf in front of field 5 with plant at full load.
1430 – Increase injection rate to 6 lb/MMacf.
1550 – First low hopper alarm.
1640 – Shut off DE rappers fields 5 and 7. CE rappers on odd side do not energize. Operator manually turned on CE 2, 3, and 4 and all three turn on.
1655 – Second low hopper alarm. Bag is not dropping correctly. Don't think we are losing sorbent flow yet.
1825 – Sorbent out.
1830 – Manually rap field 7 (DE 7, 8)
1831 – Manually rap field 5 (DE 5, 6)
1835 – Finish rapping DE.
1835:45 – Rap CE 4.
1837:00 – CE 4 off, rap CE 3.
18:39:08 – CE 3 off, rap CE 2.
18:40:00 – CE 2 off. Opacity spiked at 58 instantaneous, hit 31 6-min. Each rap cycle above caused a spike. CE 3 and field 5 (DE 5, 6) the highest.
1846:38 – CE 1 on.
1847:00 – CE 1 off. Spiked to 25.
1930 – Began shutting down all equipment.
2030 – Departed.

9/27/05
0800 – TC, JA, BH onsite
setup

9/28/05
0800 – TC, JA, BH onsite
baseline testing

9/29/05
0800 – TC, JA, BH onsite
baseline testing

9/30/05
0800 – TC, JA, BH onsite
0930 – CW onsite
1345 – Started FAS at ESP inlet.
1430 – Stopped FAS at ESP inlet.
1358 – Spent the morning installing the probe in the control side outlet duct. Analyzers have been operating fine. The outlet is reading just a bit higher than the inlet.
1530 – Collected ash samples.
1700 – Conducted staggered outlet traverse STMs. Used ports 4 and 10 at depths of 32" and 64". These depths account for the port length of 21"
1854 – Hooked up control side 3 outlet duct probe to outlet analyzer. Can't get the values to match. There appears to be an intermittent leak in the probe. Load is fluctuating. Will work on the problem tomorrow.
1900 – Left Site.

10/1/05
0800 – CW, JA, BH, CS onsite
0830 – Inlet and outlet analyzers are working fine. The control side outlet sampling train didn't stabilize over night. O2 data confirms there is a leak of some sort. Will work on the problem this morning
0845 – Prepared STM and FAS equipment for testing this afternoon. Performed various maintenance tasks.
1030 – Calibrated Porta-PAC with DARCO E10. New maximum feedrate at 200 rpm is 760 lbs/hr.
1047 – Unit is at full load.
1132 – Inlet Hg is at 9 ug/dNm, Outlet is at 10 ug/dNm.
1148 – Started DARCO E10 injection between fields 5 and 7 at 78 lbs/hr (3 lbs/MMacf) in front of field 7.
1400 – Started FAS at ESP inlet.
1456 – Increased DARCO E10 injection rate to 156 lbs/hr (6 lbs/MMacf).
1600 – Collect fly ash samples from B11, B12, B13, & B33. No ash is available in B42.
1934 – Stopped DARCO E10 injection.
2000 – Left site.

10/2/05
0800 – CW, JA, BH, CS onsite
0815 – Loaded super sack of DARCO E11 on Porta-PAC.
0817 – Noticed some particulate spikes from DARCO E10 injection yester day at 6 lbs/MMacf. This decreased as the night went on.
0900 – Analyzers are working well. Inlet and outlet control side mercury concentrations are essentially equal. The outlet test side is about 1 ug/dNm lower than the control side. The test side filter was blown back to eliminate any possible sorbent buildup on the filter.
1010 – Calibrated Porta-PAC. New maximum feedrate is 900 lbs/hr at 2000 rpm.
1208 – Inlet Hg @ about 7.1 ug/dNm, outlet Hg @ about 7.5 ug/dNm. Start DARCO E-11 @ about 78 lbs/hr (3 lbs/MMacf) in front of field 7.
1238 – Started FAS at ESP inlet.
1508 – Increased DARCO E10 injection rate to 156 lbs/hr (5 lbs/MMacf).
1605 – Collected ash from B12, B13 & B31. No ash available in B41.
1940 – Stopped DARCO E11 sorbent injection.
2000 – Left site.

10/3/05
0800 – CW, JA, BH, CS onsite
9015 – Loaded super sack of DARCO Hg on Porta-PAC.
1010 – Calibrated Porta-PAC. New maximum feedrate is 815 lbs/hr at 2000 rpm.
1140 – Started DARCO Hg sorbent injection upstream of field 7 at 26 lbs/hr (1 lb/MMacf)
1145 – Started FAS at ESP inlet.
1450 – Increased DARCO Hg injection to 78 lbs/hr (3 lbs/MMacf)
1530 – Collected ash samples.
1843 – Stopped DARCO Hg injection
1900 – Left Site

10/4/05
0800 – CW, CL, BH, CS onsite
1124 – Changed Porta-PAC maximum feedrate to 780 at 2000 rpm.
1317 – Start DARCO Hg sorbent injection upstream of field 7 at 156 lbs/hr (6 lb/MMacf).
1330 – Started FAS at ESP Inlet
1540 – Collected Ash Samples
1703 – Increased DARCO Hg injection rate to 208 lbs/hr (8 lbs/MMacf).
2137 – Stopped DARCO Hg inject
2138 – Left Site

10/5/05
0730 – BH & CS on site.
0800 – CW onsite
0815 worked on supplying compressed air to the silo. The air supply pressure is 40 psig static.
0820 – The high level switch on the silo is still alarming. The signal fuse is blown. Will work on the problem later today.
0830 – CL onsite

0900 – Started loading the silo with DARCO Hg-LH sorbent.
1304 – Started DARCO Hg-LH sorbent injection at 13 lbs/hr (0.5 lbs/MMacf).
1615 – Increased DARCO Hg-LH injection rate to 26 lbs/hr (1.0 lbs/MMacf).
1830 – CL, BH, CS left site
1916 – Stopped DARCO HG injection
1920 – CW left site.

10/6/05
0730 – BH & CS on site.
0800 – TC and CL on site.
0830 – Talked with Mike Rees, power to Porta-PAC to be disconnected this morning. Will have forklift support for Porta-PAC shipment tomorrow.
0900 – Optimization system (POS) has been turned off since 0800, 10/5. Plant is beginning to point blame on system for opacity as opposed to rapping cycles. Will have to monitor to see if that is the case.
0920 – CL changed out speed switch from Porta-PAC to silo and that fixed the problem with #2 feeder train being unable to inject PAC controllable.
0930 – Talked with Mike Rees about end of long term and ash recycle. Plant is ready to support loading silo with ash. Plant will continue to use ash with the ash handlers monitoring ash quality with the carbon injected on 1/8 of the flue gas stream.
1027 – Lost silo power when disconnecting Porta-PAC system. Reestablished new program in PLC to prevent loss of system.
1030 – CL isolated loss of air pressure to bad union fitting on silo vent filter, off to repair.
1312 – Calibrated skid feeder (train # 1). CP 20 = 734. Start injecting DARCO HG-LH @ 78 lbs/hr (3 lbs/MMacf).
1608 – Increased PAC concentration to 6 lb/MMacf for Hg-LH. PAC rate at 156 lb/hr.
1650 –Collected ash from hopper B12, B13, B22, B23, B32, B33, no ash available from hoppers B42 or B43.
1932 – Stopped PAC injection.

10/7/05
0700 - BH & CS on site.
0800 – CL and TC on site.
0805 – Porta-PAC shipment out scheduled for next Thursday. Plant ran at 530 MW through the night.
0920 – Changed out filter on test outlet Hg probe, no significant change in Hg levels. O2 cell on inlet appears to be reading high.
1000 – Snurf control side outlet filter. Wash out and results slowly recover through the day.
1030 – Inlet gold positioning fails. Recover at 1300.
1511 – Begin injecting on rear grid at 78 lb/hr (3 lb/MMacf)
1636 – Stop injecting on rear grid with outlet HgT at 2.99 ug/m3. Check calibration of feeder, injecting at 77.7 lb/hr (expected 78 lb/hr) – close enough.
1653 – Begin injecting at 78 lb/hr (3 lb/MMacf) on middle grid.
1930 Load has dropped to 625 MW. Ended carbon test and notified control room.

10/8/05
0800 – CS, CL, and TC on site.
0900 – Inlet Hg(T) sample line crystallized in chiller, other Hg(O) line OK. Clean out and repair, calibrate.
1236 – Begin injecting Hg-LH at 3 lb/MMacf, 39 lb/hr per field.
1604 – Shift to 52 lb/hr front field, 26 lb/hr rear field injection.
1824 – Secure injection.

10/9/05
0800 – CS, CL on site.
0900 – Calibrate analyzers downloaded data

10/10/05
0800 – CS, CL, and TC arrived on site.
0830 – Began calibrating analyzers. Data from previous day looks like it takes about 18 hrs and full load for the inlet and outlet Hg(T) numbers to match up.
1548 – Commence long term testing at 4 lb/MMacf concentration (104 lb/hr max flow rate).
1700 – No ash samples today as hoppers not isolated.
1800 – Hg(T) outlet slowly coming down to expected range.
2200 – Load decrease begins, sorbent appears to be following load.
2230 – Sorbent injection trending down with load.

10/11/05
0800 – CL and EZ on site.
0815 – TC on site.
0820 – Sorbent injection is running slightly higher than expected, 54 lb/hr at 400 MW (expected injection rate is 48 lb/hr).
1600 – All equipment appears to be running well. Mike Rees has called about opacity. BHAs are agreeing with plant equipment that opacity is spiking. TEOM is down hard.
1800 – TC & EZ leave site

10/12/05
0800 – SM and EZ on site.
0810 – TC on site.
0830 – Walk down equipment, all appears to be operating correctly. Recalculate injection rate, system is working fine.
1400 – Changed field 7 rapping duration from 140 to 70 seconds. 6 min opacity following rapping has reduced from roughly 20% to less than 10%.

10/13/05
0800 – SM and EZ on site.
0810 – TC and CW onsite.
0955 – Plant technician is working on the opacity monitor. Readings are not reliable at this time.
1015 – Worked on replacing the silo pressure switch.

1330 – Calibrated train 1 feeder. CP-20 was set at 734 lbs/hr at 2000 rpm. This value was left the same.
1315 – Started FAS at ESP inlet.
1349 – Collected a few ash samples.
1549 – Collected ash samples.
1700 – Leave site.

10/14/05
0800 – SM and EZ on site.
0845 – CW onsite.
0955 – Notice some small problems with analyzer operations. Will be performing minor maintenance. See analyzer logbook for details.
1700 – Left site

10/15/05
0900 – CW onsite
1000 – EZ and SM onsite.
1200 – Performed analyzer maintenance. See logbook for details.
1741 – Performed more analyzer maintenance. Mercury data is spikey and elevated at the outlet.
1742 – Left site.

10/16/05
0900 – EZ and SM onsite
1200 – CW onsite
1600 – Increased ACI to 5.0 lbs/MMacf.
1614 – After evaluating the analyzer operation and performing several trouble shooting and diagnostic tests, still cannot determine the cause of the spikey data or the elevated outlet mercury levels.
1615 – Left site

10/17/05
0800 – CW and SM onsite.
1021 – Worked on some more outlet analyzer maintenance. See analyzer log for details.
1123 – Analyzer maintenance seems to have fixed the spikey data. Outlet analyzer is currently reading 2.4 and rising due to load ramp.
1330 – Field 7 rapping schedule was changed to rap every to hours.
1700 – JA onsite
1835 – After switching the sample lines between the two analyzers, there was no change in the mercury concentrations. This indicates both analyzers are operating properly. Overboard calibrations on EMC 2 also agree. The Increase in Hg concentration observed after 10/14 at noon can only be explained by properly blowing back the filters every day. Prior to this time, the blowback procedure was not done at high enough pressures.
1900 – Left site.

10/18/05
0800 – CW, JA, and SM onsite.
1128 – Analyzers are still operating well. Today OH runs will be completed. STMs will also be collected.
1200 – Started first OH run.
1320 – Started STM at ESP outlet
1700 – Started Second OH run.
1707 – Started STM at ESP outlet
1708 – Started FAS at ESP outlet.
1830 – Left site.

10/19/05
0800 – CW, JA, and SM onsite.
1128 – EMC 2 (outlet) froze up during data download. Working on restoring operation.
1230 – Started 3rd run of OH testing.
1345 – Started STMs at the ESP inlet
1440 – Started FAS at ESP inlet.
1530 – Complete FAS.
1630 – Complete 3rd run of OH testing. Depart site.

10/20/05
0800 – TC, JA, SM and CW on site.
1000 – CW departs after turn over.
1005 – EMC-2 continues to have problems, desorb file corrupted again. Restore operation at 1020 without desorb data
1030 – EMC back in operation. Most of the data recovered.
1300 – Continuing to have removal problems, attaining 80% with 5 lb/MMacf Hg-LH is proving elusive. All indications are analyzers are functioning correctly. Could be an issue with a plugged grid or potentially a different carbon (most of the parametrics performed with supersacks, long term done with silo)
1600 – Talk with office and decide to swap from rear to front grid to verify removal and potential grid blockage.
1700 - Depart site at 5 pm.

10/21/05
0800 – TC, JA, and SM arrive on site.
0846 – Swap to front grid injection, load holding steady at 390-400 MW. Complete swap at 0850. HgT outlet levels fall from 1.9 to 1.3. Will monitor this afternoon for follow through.
1000 – Analyzers OK. Talk with office. Continue to monitor situation with Hg removal rates.
1300 – Talk with Steve Coker, plant, to discuss rapping cycle. Steve wants to keep cycle for rear grid at 2 hrs. Will discuss with Mike Rees on Tuesday concerning decreasing back to 1 hr to verify no impact on Hg removal.
1500 – Traverse outlet test side with 4 STM traps.
1900 – Depart site.

10/22/05
0800 – TC, JA, SM on site.
1000 – Analyzers OK.
1200 – Check equipment, no problems with delivery.
1830 – Depart site.

10/23/05
0800 – JA, TC and SM on site.
0830 – Calibrate and download data.
1200 – Lose feed in #1 train. Try to start #2 sorbent, but won't start. #2 blower breaker tripped, reset and started blower. Lost feed on #1 due to individual hopper legs isolating flow with 6k lbs of sorbent left. Fix after 1 5 min off-line.
1400 – Depart site.
1900 – Arrive site to check equipment.
2000 – Depart, all equipment functioning OK.

10/24/05
0830 – Carbon arrived and the starting weight was 4360.
0945 – Finished with the carbon loading with a weight of 39330.
1110 – Stopped feeding carbon, calibrated silo. Injection was running low by a small factor. Changed CP-20 to 655 from 734.

SP	Wght	Time
120	3.48	120
60	1.76	120

Changed CP-20 to 650

120	4.14	120

Changed CP-20 to 655.
1130 – Began injecting carbon.
1352 – Stopped carbon injection to shift to rear field.
1354 – Began carbon injection on rear field but it had a leak on a hose. Restarted on front field at 1400.
1403 – Changed SP in PLC to 655 since it is controlling.
1500 – Began rear field injection.
1600 – Conference call.
1700 – Continue to have problems with the STM boxes: leaks, unable to communicate, etc.
2021 – Finished STM on outlet with rear field on line.
2022 – Shifted to front grid injection.
2030 – Departed site.

10/25/05
0730 – Arrived on site. TC, JA, CL, SM
0930 – Calibrated analyzers. Performed overboards on inlet, check within 10%. Mercury calibrator use is questionable since have not succeeded in lab tests. Will begin testing on Thursday after OH runs.
1300 – Release OH crew to begin testing.
1330 – Begin run 1 of OH testing, begin BHA tuning at 1345

1545 – OH run 1 complete.
1705 – OH run 2 started.
1930 – OH run 2 complete.
2000 – Departed.

10/26/05
0730 – CL, BH on site.
0800 – TC on site.
0945 – Calibrate analyzers, blow back.
1230 – Commence run 3 of the OH. Start STMs at ESP inlet
1250 – Run CPM stack test at ESP outlet
1530 – Collect ash samples
1700 – Ran overboards on EMC 1 and 2
1800 – Left site

10/27/05
0730 – CL, BH, CW on site.
0945 – Calibrate analyzers, blow back.
1400 – Started FAS
1509 – Collect ash samples.
1630 – Left Site

10/28/05
0730 – CL, BH, on site.
0800 – CW onsite
0920 – Calibrate analyzers, blow back.
1008 – Started FAS
1201 – Removal efficiencies while injecting on the back grid (10/18 through 10/20) the removal efficiency was about 57.6%. When the new sorbent was delivered on 10/24 the mercury removal increased to 74.3% (10/22 – 10/23). After moving to the front injection grid (10/22). The removal efficiency remained the same at 73% (10/27 – 10/28).
1430 – Collected Ash samples.
1626 – Left site

10/29/05
0830 – CL, BH, & CW on site.
1747 – Worked with the Cavkit all day on the inlet and outlet analyzers. Results are described in detail in the analyzer logbook.
1802 – Left site.

10/30/05
0830 – CL, BH, & CW on site.
1038 – Increased ACI injection rate from 5.0 lbs/MMacf to 8.0 lbs/MMacf. This will be short. 3-hour test to see if Hg removal can be increased by increasing the sorbent injection rate. Prior to increasing the injection rate, the average inlet Hg concentration was

7.36 ug/dNm while the outlet concentration was 3.16 ug/dNm, representing 56% Hg removal. Boiler load is currently 740 MW and stable.
1402 – After injecting sorbent at 8.0 lbs/MMacf for a little over 3 hours, there was no noticeable increase in Hg removal. The inlet mercury concentration was at 7.12 ug/dNm while the outlet concentration was 3.23 ug/dNm, representing a removal efficiency of 55%. Decreased sorbent injection rate to 5.0 lbs/MMacf. Boiler load during the test varied between 800 and 719 MW.
1524 – Worked with the cavkit on the control side outlet throughout the day.
1530 – Left site.

10/30/05
0803 – CL, BH, & CW on site.
1326 – Spent the morning working on the analyzers. The outlet analyzer had some moisture in it due to the chiller being overloaded with flush water. The analyzer and hotline were cleaned and place back in service. The inlet analyzer gold was changed.
1327 – ColoWyo coal will be fired today. It is expected that the coal will begin hitting the boiler around 1230.
1200 – Started FAS.
1504 – Collected ash samples.
1538 – Inlet is now at 2.5 ug/dNm and the outlet is at 0.8 ug/dNm, representing a 66% removal rate.
1600 – Left site

11/01/05
0800 – CL, BH, on site.
0810 – CW and CS onsite.
0900 – Everything is working fine. The inlet Hg concentration is about 3.0 ug/dNm while the outlet is 0.08 ug/dNm.
0901 – CL left iste.
1039 – Isolated ESP hoppers to collect ash samples later today.
1330 – Started first OH run.
1331 – Started FAS and STM at ESP inlet.
1620 – Started second round of Ontario Hydros
1640 – Unit load has dropped. Control thought we were done testing for the day.
1748 – Second OH run aborted due to load variance.
1800 – Left site.

11/02/05
0750 – CS, BH, and CW on site.
1400 – Started FAS at ESP inlet
1415 – Started OH run.
1445 – Collected ESP hopper ash samples.
1640 – Completed OH run.
1710 – Left site.

11/03/05
0650 – CS, BH, on site and ready to work.
1538 – Site meeting.
1548 – Left site.

11/04/05
0730 – CS & BH on site and ready to work.
0800 – TC on site.
1015 – Return full power to ESP B electrical fields 5 and 7. Opacity immediately decreases.
1627 – Stop injection to calibrate.
1645 – Start injection at 3 lb/MMacf. Calibration: 120 lb/hr feedrate – 2 min – 4.05 lbs: OK
1730 – Left site.

11/05/05
0720 – CS & BH on site and ready to work.
0820 – TC on site.
17:30 – Left site

11/06/05
0730 – CS & BH on site and ready to work.
0825 – TC on site. Train 1 has had two hopper fill alarms but still putting ACI in. Silo wt at 4500 lbs, will need to switch legs here shortly.
1630 – Left Site

11/07/05
0750 – CS & BH on site and ready to work.
0815 – TC on site. Feeder 1 tripped at 0520 due to low hopper level. Calibrated and began feeding on Train 2 at 0845. Cal: 120 lb/hr feedrate (manual) – 2 min – 3.87 lbs.
0930 – Informed by Mike Rees that ColoWyo is on the conveyor belts and will be fed for some period of time – until Wednesday.
1305 – Turn off ESP B electrical field 5.
1450 – Refill silo with recycle ash without blowing it up to 17,600 lbs.
1713 – Increase injection rate to 5 lb/MMacf.
17:35- CS & BH leaving site
1845 – Reenergize electrical field 5.
1850 – West (Test) CPM is not functioning correctly.
1900 – TC departs site.

11/08/05
0730 – CS & BH on site and ready to work.
0800 – TC on site. Shifted injection to Train 1 and sampled Train 2.
0900 – Test side BHA back on line. Needed to be reset for some reason. Will continue to monitor.
1327 – Shifted to Train 2 and sampled Train 1.
1511 – Shifted to Train 1. Feeders off-on train #2. Leaking oil from Train 2 rotary gearbox. T/S and find that gear box fill cap is plastic and the threads are worn. Valve was running for

an 1.5 hr, gear box got hot, oil expanded and ran out through cap which cannot maintain a tight seal. All other components appear to be working OK. Will check to see why hopper would not fill. Train 1 seems to be feeding OK.

11/09/05

0720 – CS on site and ready to work. SM on site.
0815 – TC on site. Lost opacity and all CEMs inputs into computer yesterday at 10 am.
1000 – Shift to Train 2 feed after filling hopper. Had to mechanically agitate silo. Began calibrating Train 1:
Run 1: 120 lb/hr designated feedrate – 2 min – 9.45 lbs = 283 lb/hr.
Change Feedrate SP to 755 from 655
Run 2: 60 lb/hr – 2 min – 4.23 lb = 126 lb/hr
Change Feedrate SP to 855 from 755
Run 3: 60 lb/hr – 2 min – 3.67 lb = 110 lb/hr
Will assume feedrate is doubled using this sorbent combination.
1145 – System back on line. Feeding at 1 lb/hr on Train 2. PLC faulted twice, Train 1 will not come up to discharge pressure.
1200 – Regain CEMs data.
1201 – Ash recycle is full in (now feeding from) at the silo.
1330 – All TEOM gear down except for box.
1615 – T/S train 1 discharge motive pressure. Blown gasket. Tighten to increase discharge pressure to 7.5 psig. Lost sorbent feed at 1630 temporarily.
1715 – Depart.

11/10/05

0740 – SM, EZ, TC on site.
0830 – Shift to Train 1 feeding at 1 lb/MMacf (0.5 lb/MMacf indicated).
Train 2 calibration: 15 lb/hr feedrate SP – 5 min – 2.04 lb = 24.5 lb/hr. Both sides holding at twice indicated feedrate.
1000 – Train 1 had a bridge problem, had to bang on silo to release sorbent into the hopper. Looks like ash-sorbent compacts much more readily than carbon by itself. Density may be an issue there.
1000 – TC left site.
1030 – Replaced outlet test side probe.
1120 – Started FAS.
1300 – Completed FAS.
1330 – Trends in Total Hg concentrations seem to be consistent with coal changes (to ColoWyo on 11/7 and back to PRB on 11/10). Outlet measurements seem to be increasing very slowly to 4.5 ug/Nm3 (40% removal). Increase not believed to be related to probe change. Need to wait and be sure it is stabilized for proper study.
1530 – Removal rate continued to decrease to 16%.
1632 – Increased injection rate to 2.0 lbs/MMacf.

11/11/05
0800 – SM, EZ, CW on site.
0916 – Switched operating trains on the silo. Had some trouble starting the blower. The breaker keeps tripping in and out.
1130 – Started FAS
1315 – Collected ESP hopper samples.
1423 – Eductor suction pressure is getting lower and lower as the day goes on. Blower pressure is also increasing. Could be due to some plugging. At the start of train 2 injection, the blower pressure was 9 psi. Now the pressure is 10 psi. The eductor suction valve is slowly being closed to ensure eductor suction pressure. Need to keep a close eye on blower performance.
1450 – Switched to train 1. Collected sample from train 2.

11/12/05
0830 – SM, EZ, CW on site.
0831 – Skid experienced some hopper fill malfunctions last night. Fixed itself.
0840 – Increased ACI to 4 lb/MMacf.
1015 – Switched train 1 and 2. Collected sorbent sample from train 1. Train 2 eductor suction pressure is 2" H2O wile the blower discharge pressure is 10.25 psi. Watch this today to see if eductor is plugging.
1041 – Starting ESP outlet staggered STM traverse.
1234 – Started FAS.
1350 – Stopped FAS.
1400 – Completed last STM run at ESP outlet.
1450 - Train 2 eductor suction pressure is 2" H2O wile the blower discharge pressure is 10.25 psi.
1450 – Left site

11/13/05
0830 – SM, EZ, CW on site.
0831 – Train 2 tripped off on low eductor suction pressure at 1730 on 11/11. Will investigate.
1121 – There is very little suction on the eductor suction port. After comparing the filed 7 grid to the field 5 grid, it appears that the filed 5 grid is plugged. After looking at the sorbent trend it appears the skid started and stopped for about an hour as the eductor suction increased and decreased. The grid was pulsed with compressed air and also sucked on using an eductor. Some of the grid has been cleared up.
1124 – Restarted injection on grid five at 6.0 lbs/MMacf. The eductor suction pressure has been adjusted to 2.0 in H2O while the blower discharge pressure is 11.0 psi. These values will be watched throughout the day.
1400 – Measuring inlet and outlet total Hg on EMC 1.
1423 – After throttling down the eductor port, still continuing to have eductor suction pressure alarms. Stopped train 2 feeder.
1608 – Left site.

11/14/05
0800 – SM, EZ, CW on site.
1000 – SM dismantled the outlet control assemblies.
1340 – Started emptying silo into the ESP inlet. Both trains are operating. Feeding at approximately 600 lbs/hr. Train 1 is running at 225 lbs/hr while train 2 is operating at 375 lbs/hr due to the blower leak on train 1.
1600 – Started to reassemble probe, taken from the outlet control and shortened the probe length to 48”. This was placed in the port next to the outlet test probe.
1800 – Completed building the probe and assembly.
1815 – Installed two probes on the test side outlet duct. On probe is into the duct 50”, the other probe is into the duct 26 inches. The total duct depth is 76 inches.
2341 – Finished unloading and loading silo
2359 – Left site.

11/15/05
0800 – SM, EZ, CW on site
0815 – Vacuumed injection grids using a sucker truck. There is some indication that the grids were cleared up because the vacuum would decrease during the process. Each grid was sucked for 10 minutes. There is also more suction observed on the injection grids.
0930 – SM left site for airport.
1108 – Fixed test side CPM 5000. The controller needed to be reconfigured.
1334 – The vacuum truck seems to have cleared the front grid up somewhat. Suction on the rear grid and front grid are essentially equal. When connecting the hoses to train 1, the eductor suction pressure without the blower running is 1” H_2O for both trains. When comparing the suction upstairs, all four grids have about the same suction.
1335 – Filled train 2 hopper with sorbent. This is 100% DARCO Hg-LH. Train 1 hopper may still contain some recycle material. Will need to calibrate both trains after the sorbent has defluidized.

APPENDIX C2: EPRI Extended Test Log—March 11, 2006

EPRI Extended Testing Log

11/16/05
0730 – CW and CS on site. Install plugs for measuring system pressures.
1645 – TC on site.
1730 – Talk to operators. Begin to prepare system for start up.
1839 – Begin injecting from Train 2 on Field 5 grid at 4 lb/MMacf with Hg-LH. ESP B fields 5 and 7 running at full power, unit running at 840 MW. Initial inspection seems to be everything OK.
1915 – Depart site.

11/17/05
0730 – CS on site.
0810 – TC on site. Injection working fine.
0850 – T/R B-5 turned off.
1146 – Calibrate train 1:
1.7# – 60 lb/min – 2 min – 735 SP
3.5# – 120 lb/min – 2 min – 735 SP
4.1# – 90 lb/min – 2 min – 700 SP
1149 – Turn off train 2 and start train 1 feeding from silo.
Check calibration on train 2:
2.5# - 90 lb/min – 2 min – 735 SP
Injection concentration was running 18% low. So injection concentration of 4 lb/MMacf was actually 3.25 lb/MMacf. Need to check against silo weight usage rate.
Since about 9 am, chiller on inlet froze and CS has been working to repair.
1500 – Analyzer fully functional again.

11/18/05
0730 – CS on site.
0815 – TC on site.
0830 – Plant load is at 800+MW and inlet HgT running at 3.6ug/m3. CS beginning to find out cause of problem. Outlet is running at 2.7 ug/m3, with 4 lb/MMacf injection, should be a good number or close to it.
0855 – Increase injection rate to 5 lb/MMacf on Train 1. ESP T/R set B-5 still off line.
0930 – Looking at analyzer data, the inlet is reading significantly low for load. Isolate cause to the "A" channel isolation valves scrubbing. CS to clean.
1300 – Everything appears to be running correctly.
1600 – Change out a Balston filter and add another impinger to inlet train. Still getting some scrubbing on the inlet.
1900 – Depart site, data looking OK.

11/19/05
0730 – CS on site. Equipment running well.
0830 – TC on site. Update ftp site.
0915 – T/R set B-5 back on line.
1120 – Switched to both channels on outlet

1400 – Duct tape patch covering newly tapped holes came off on far lance. Smelled carbon and found small pile of carbon. Repatched hole.
18:00 – CS left site

11/20/05
0730 – CS on site. Analyzers running well.
0930 – Test side CPM reading zero. Rebooted and started back up.
1730 – CS left site

11/21/05
0730 – CS on site. Analyzers running well.
1058 – updated FTP
1135 – Switched Channel A on the analyzer to the Outlet.
1325 – Switched back to Inlet, analyzers correlate well.
1455 – Stopped sampling, began shutdown procedures
1616 – Stopped carbon injection. Notified that plant has tube leak and will be shutting down as well.

11/28/05
TC and CL travel to site.
1545 – TC on site. Bump start all silo equipment, walk down site.
1730 – Depart site.

11/29/05
0730 – CL on site. Begin assembling the analyzer.
0745 – TC on site. Prep silo for start up. Talk to Mike Rees, ID fan for A-C ESP is down, unit 2 limited in power.
1500 – Analyzer on line.
1648 – Begin injecting at 6 lb/MMacf. Plant is only running on one ID fan, so air flow is high for indicated power. Removal rates should be low. Prior to sorbent start, Pressure at the grid is (-)3.5” w.c. for both injection posts on grid between field 3 and 5.
1800 – Departed site.

11/30/05
0745 – TC and CL on site. Analyzers running fine.
1008 – Increase indicated injection rate to 10 lb/MMacf.
1425 – Shift to Train 2 injection. Check calibration.
Train 1 – 2 min – 150 lb/hr – 5.07 lbs
Train 2 – 2 min – 150 lb/hr – 4.84 lbs
1452 – Tripped Train 2 on high blower discharge pressure. Reset and restarted, looks OK.
1520 – Lowered B-7 power to 50%.
1715 – Departed site.

12/1/05
0745 – TC and CL on site. With B-7 off for the night, no apparent problems with opacity. Overall opacity levels did rise slightly, from below 5% to above 5%.
1047 – Increased injection rate to 12 lb/MMacf (430 MW=190 lb/hr). Pressures at injection grid penetration at (-)0.5 in (W) and (-)0.2 in(E) w.c.
1615 – Departed site.

12/2/05
0745 – CL on site.
0830 – TC on site. Inlet drain line leaking. Repairs underway.
0953 – Increased indicated injection concentration to 15 lb/MMacf. (237 lb/hr)
15:30 – Plant is installing ID fan motor
16:47 – Reduced injection to 5 lb/M

12/3/05
0730 – CVL on site. ID fan has been installed and load is ramping up. It appears from the opacity trace that the fan was put into service around midnight.
1340 – Unit went to 744 MW for an hour or so and then back down to 370 MW.
1400 – Unit holding ~ 400 MW. Injection rate is 5 lb/M (78 lb/hr). Removal is 70%.

12/4/05
0730 – CL on site. Unit is ramping up to full load. Injection rate remains at 5 lb/M. Injecting 113 lb/hr.
1030 – Unit load back down to 375 MW. Injecting 78 lb/hr.

12/5/05
0645 – CL on site. Unit is ramping up in load. Injection rate remains at 5 lb/M.
7:00 – Problems on inlet and outlet sample trains.
0830 – Load of carbon onsite to unload
0915 – Begin unloading carbon
0930 – Working on sample problems
11:20 – Carbon fill complete. Analyzer is still off line.
14:00 – Leaving site. Lots of problems remain (see lab notebook). Chad to come in later.
17:00 – Chad arrived on site to fix equipment.
18:15 – After thorough assessment determined that it is not possible to get either inlet or outlet operational. Partially covered both locations with tarp.

12/6/05
0900 – Low pressure alarm activated. Airline to skid improperly connected. Reconnected to dry air line. Valve also left open on line behind fill line.
0730 – Arrived on site Injection rate remains at 5 lb/M.
1915 – Leaving site

12/7/05
0720 – Arrived on site. Steve arrived to assist Chad in fixing everything. Injection rate remains at 5 lb/M.

12/8/05
0730 – Arrived on site. Injection rate remains at 5 lb/M.

12/9/05
0730 – CS Arrived on site. Injection rate remains at 5 lb/M.
1500 – Increasing injection rate to 6 lb/M

12/10/05
0730 – Arrived on site. Injection rate remains at 6 lb/M.
1403 – Increased injection rate to 7 lb/M

12/11/05
0800 – Arrived on site
1150 – Noticed that test side CPM is not responding. Will cycle power after lunch.
1300 – Cycled power on CPM, no change
16:26 – Increased injection rate to 8 lb/M
17:08 – After discussing Hg levels w/ Tom C. Decided to decrease injection rate to 5 lb/M

12/12/05
0745 – CS, PB and SM on site
1430 – Brignac, Sapp use scale in plant Chem Lab to mix sorbents for high load SSD testing
1600 – CS leaves site
1730 – PB, SM leave site

12/13/05
0715 – PB and SM on site
0800 – ACI rate at 5#/MMacf. Per Todd Blackberry Unit can't hold full load for very long this AM. Will get us 5 hours at full load this PM for STM tests.
0830 – Move outlet probe equipment to access sample port for STM traverse, standby for full load notification. Received notice will have full load from 6–10 PM tonight.
1100 – Pressures at injection grid penetration at (-)2.0 in (W) and (-)3.0 in(E) w.c., but at low load 369 MW.
1330 – Upload to FTP. Modrak prepares sample tubes for SSD
1800 – Start STM traverse; 3 different ports, two depths at each port.
2000 – Pressures at injection grid penetration at (-)4.0 in (W) and (-)4.50 in(E) w.c., but at high load 875 MW
2200 – Finish STM traverse; pulled ~ 25 liters through each trap.
2215 – PB and SM leave site

12/14/05
0500 – SM on site. Plant starts ramp to full load. Today plant will hold full load from 6 – 10 AM, and then again, from 6 – 10 PM.
0530 – PB on site
0600 – ACI rate at 5#/MMacf. Plant at full load. Modrak starts 1st SSD

0800 – Todd Blackberry calls to let us know plant will be switching to ColoWyo fuel, sometime early this afternoon. Todd was informed that high load from 6 – 10 PM today was not required.
1000 – Sorbent screening tests complete. Plant comes off load.
1200 – SM leaves site to travel home.
1400 – Traps from high load STM traverse packaged for shipment to Frontier. Original run sheets placed in folder in ADA trailer.
1500 – Resend daily data to FTP site. Site was full earlier today.
1600 – PB leaves site

12/15/05
0800 – PB on site. Plant ramping down from full load. ACI remains at 5#/MMacf.
0900 – Hg numbers very low on inlet and outlet. Plant must be burning ColoWyo.
1000 – Upload to FTP. Pack and ship SSD samples to ADA via UPS.
1400 – 18600# in Silo
1600 – Talk to Tom C
1620 – Restart test side BHA. Low value indicates rescaling necessary
1700 – PB leave site

12/16/05
0800 – PB on site. Plant ramping down from full load. ACI remains at 5#/MMacf.
0900 – Hg beginning to climb back up, indicating ColoWyo coal has worked its way through the system.
0930- EMC-2 Locks up on data download. Replace with EMC-1. Last HgT on EMC-2 screen was `7 inlet, 3 outlet (corr)@ low load.
1200 – Enter new "B" coefficient (value=20) into test-side BHA panel. Now matches control side.
1700 – Left site

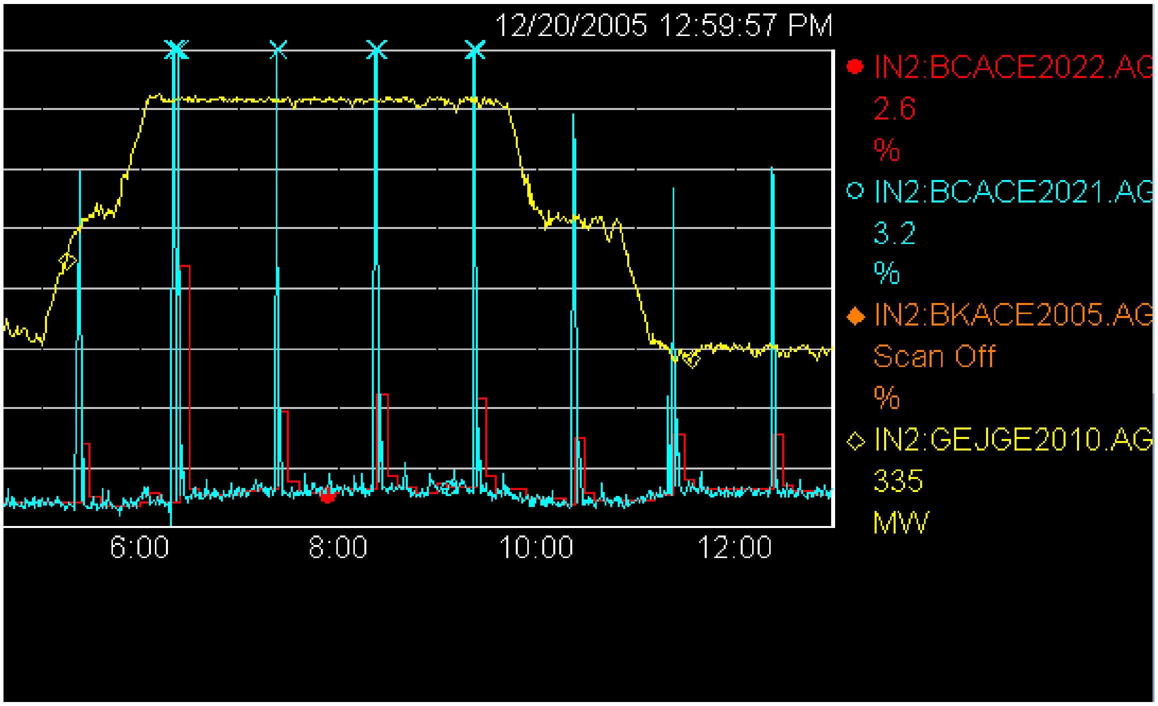
12/17/05
0730 – PB on site. Plant ramping down from full load. ACI remains at 5#/MMacf.
0830 – Hg ~10+ inlet, 4+ outlet. EMC-1, definitely back in PRB
0900 – Had to stop and start CPM test side due to Temperature fault.
1000 – Couldn't create plant data sheets for missing days 11/21 – 11/27. All cells "no good data available". PI data files may not hold that far back. Tom to check on this.
1249 – ACI to 8#/MMacf. Unit at low load; no opacity spikes
1630 – 13700# left in SILO, still running 8#/MMacf
1700 – left site

12/18/05
0730 – PB on site. Plant ramping up to full load. ACI remains at 8#/MMacf. Opacity is acceptable.
0830 –Cycle power on test side CPM to clear temperature fault. Spend much of the day, leak checking analyzers, impingers because 02 on "A" is high. Sometime during that process, the inlet Hg readings started coming in lower than expected, so am thinking about installing a clean sintered filter tomorrow AM. When blowing back the filter witnessed wet brown ash

coming out calibration port. It's a little slow doing all this by yourself, but hope to be ready for test of ACI into field 7.
1800 - left site

12/19/05
0730 – PB on site. 836 MW. ACI remains at 8#/MMacf. Opacity is acceptable,
0830 – Start changing sintered filter on inlet probe
0930 – Talk to Todd Blackberry about injecting into Field 7 this PM. He said he would talk to Steve Coker about doubling the rapper frequency and disabling POS system. So far 8#/MMacf has not shown any negative effects to the ESP.
0945 – Continue trying to change filter. Had some thread galling issues, the elevator was locked out, or out of service, and other minor things so finished at 1130
1130 – First two scans on inlet 8.9 and 8.7 corr, were 3.2 before changing filter. Still at low load, 380 MW. outlet still okay.
1430 – Stop train 2. Reconfigure hoses for two trains into unit 7 (was 112#/hr for 8/MMacf 360 MW, single train). Baseline dP injection lances both -4 "wc
1500 – Inlet Hg climbing, now 11.5 corr, analyzer calibration very good.
1519 – Both trains running at 3#/mmacf each (44#/hr each) Train#1: 8 psi blower, 1" eductor vac, 123 rpm@44#, Train 2; 10 psi blower, 1.5" eductor vac, 120 rpm@44
1630 – Restart BHA. Work on outlet probe. HgTin 11.25, HgTout 2.4
1800 – Upload data
1830 – Leave site

12/20/05
0730 – PB on site. 838 MW. ACI remains at 3#/MMacf/train. Train 1 hopper is empty this AM. Train 1 injection stopped at 1240 AM, therefore we got 9 hrs and 20 minutes at the 6# rate into field 7, before we lost Train 1. Agitated the pants leg and rotary valve, but still no flow. Also back seal on train2 rotary valve is blowing carbon when operating. Opacity is acceptable. 6 min avg spikes to 10 when rapping.
1020 – Both trains now feeding. The carbon finally began to flow after agitation. This kind of maintenance procedure would not be desirable in a commercial system.
1050 – 5000 lbs left in Silo.
1120 – (-) 4" east injection grid, -5" west injection, 10.8 HgTin corr, 3.80 corr out
1243 – ACI to 8#/MMacf



1420 – Outlet showing unusual spiking

<u>12/20/05</u>
0730 – Arrived onsite. Plant at full load. Injection at 8#/MMacf
0800 – B1 (outlet SnCL2 impinger) is dry this AM. Pump lost suction because 13 ga tygon got loose in ¼" PFA tube in the Stannous jug sometime over night. Since everything was flowing when I left site yesterday, I don't think yesterday afternoons spiky data could be attributed to this.
0810 – Refilled Stannous impinger, replaced feed tubing
0837 – Train 2 hopper empty. So injection down to 4 #/MMacf
0920 – Stopped Train 1. Carbon Injection now 0.
1140 – Stop analyzer, download data.

<u>1/18/06</u>
0730 – CS, CL on site
0800 – Plant coming off-line until Friday. Going to fix lance problem today and tomorrow.
0900 – Received carbon shipment from Norit
12:30 – The plan for getting the work done in the ESP is as follows

The ESP should be cool enough to enter by ~15:00 The crew will install the scaffolding and cut out the bottom 2/3 of the lances. The super sucker will arrive at 5:00 in the morning to get the grid sucked out

Tomorrow TC will be on-site tomorrow to supervise the new lance installation.
1630-Left site

1/19/06
0700 – CS, TC on site. The ESP was not ready to enter by 17:00. Plant pushed off work until today to give the ESP more time to flush out.
0900 – Plant team enters ESP, cuts off field 5 injection grid lower lance section. Most lances fully plugged above the ¾ to ½ in transition point.
1200 – Finish rodding out lances. Lances which are end of horizontal distribution tube on each grid furthest from door still appear to have plug problems. But may be caused by carbon in the horizontal distribution leg. Unable to clear. Good enough for testing.
1400 – Inspect field 7 grid after field 5 grid welded back together. Some lances probably plugged above lower transition, most are clean to bottom.

1/20/06
0700 – CS Arrived on site. Plant not generating any MW yet. Seem to be firing up boiler by heavy opacity problems
1430 – Plant started to produce MW, stopped venting stream
1630 – Plant at 269 MW. Talked to control room. Since there is no call for load they are going to step it up and down all night and into tomorrow most likely.

1/23/2006
07:30 – CS arrived on site.
12:20 – Started carbon injection at 1.5#/MMacf on both trains

1/24/06
0715 – CS and CL on site
1347 – Train 2 level alarm on site activated feed rate at zero.
14:00 – 16:00 – Problems with the silo feed. Train 2 hopper did not fill. Carbon may have hung up in the pant leg. Beat on the pant leg with the rotary valve in manual until the hopper was filled. While working on train 2, train 1 blower tripped on low motive air. When blower 1 was restarted the pressure was only 5 psi (8-10 being normal). Fiddled with the plastic pressure relief valve among other things and got the pressure up to 6 psi. Reset the lower trip point to 5 psi and restarted the train. (Checked blower 1's pressure against blower 2's pressure gauge and it was 5 psi) Attempted to restart train 2 but the blower would not start. Fearing problems with the controller or RS view, restarted the computer and cycled the skid power. The problem did not go away. Found the breaker inside the control panel for blower 2 tripped. Reset the breaker and started train 2. Blower tripped off again on low motive air. This time the problem was that the pressure was slightly over the high set point (10 psi). Raised the high set point to 11 psi and restarted the train.

At this time blower 1 is operating at 6 psi and blower 2 is at 10 psi. No explanation as to why things fell apart the way they did.

16:10 – Increased injection rate to 3.0 #/MMacf on both trains.

1/25/06
0725 – CS, BH on site
Train 2 stopped feeding in middle of night. Alarm sounded at 11:47 PM
I changed the settings on the test BHA per Dave's instructions. Set 4-20 ma loop to trailer to 250 mg/m3. (CVL)
1800 – BH left site. CVL will be starting STM sampling at ESP inlet, ports 4, 7, &10.

1/26/06
0710 – BH on site. CVL on site early to start STM sampling at ESP outlet, ports 4, 7, & 10.
1015 – Plant informed us that they had to drop load. We will have to finish port # 4 at high load tonight between 1800 – 2200 hrs.
1830 – Load at 743 MW. Start sampling at Port # 4 (ESP outlet).
2000 – End STM Test.

1/27/06
0730 – BH & CVL on site. Ship STM boxes to Conesville.
0800 – CL left site.
Plant had been running at high load (~800 MW) this morning from about 0600 to 1000, then dropped load to about 250 MW most of the day. Hg removal has been fairly high (~80%) during this period.
1630 – Left site.

1/28/06
0730 – BH on site.
1200 – Changed out SnCl2 impingers and cleaned out sample line between last impinger and chiller (both inlet and outlet). During this time (~0930 to ~1030 hrs) plant switched to ColoWyo coal.
1530 – Finish transferring data.
1600 – Left Site

1/29/06
0800 – BH on site.
1200 – EMC computer had locked up over night. I hooked up hyper terminal to diagnose the fault. The diag2 file was corrupt, deleted file and calibrated analyzer.
1302 – Train 12 hopper fill malfunction alarm on silo, train 2 @ 0 PPH. Started carbon flow through silo cone, into hopper with a few smacks of a hammer. Acknowledged the alarm.
1315 – Current feed rate = 59 PPH train #2, 56 PPH train #1. Boiler load at 571 MW.
1500 – Left site

1/30/06
0700 - BH on site. Silo seemed to run well all night, no alarms.
1215 – SnCl2 drain line @ ESP outlet ruptured overnight. Changed out all tubing at ESP in and out and leak checked. No leaks detected.
EMC running well, not seeing a lot of change in Hg at ESP outlet. ESP inlet Hg seems to follow the load fairly well.
1300 – Silo mid-level alert alarm. Currently at 20,310 lbs (18% full)?
1630 – Left site.

1/31/06
0700 – BH on site. Silo running well, no alarms overnight. Currently feeding at ~77 lbs/hr (train #1 & #2), plant at 800 MW.
1215 – EMC computer locked up this morning just before calibration. Found 2 bad files, diag1 & desorbc. Deleted both files. EMC is running well for the time being.

2/01/06
0730 – CS and BH onsite. Train 2 hopper fill alarm sounded at ~5:30. Fixed at 7:45
0753 - Trian #2 fill alarmed again. Had to hammer on cone to free up carbon flow.

2/02/06
0730 – CS arrived on site. Carbon getting low, estimate about 5 days worth.
18:00 – Leaving site. Just watched the control room ramp from 575-850 MW in 15 min…wow.

2/03/06
0730 – CS arrived on site. Switched from EMC2 to EMC1.

2/04/06
0730 – CS arrived on site. Nothing noteworthy, things just ran smooth

2/05/06
07:30 – CS on site. Hg levels really low, but trending nicely. Checked w/ control room switched to ColoWyo at ~4 am hit the boiler at ~8 am. Train 2 malfunction alarm sounded at 13:15. Agitated to see if that works.

2/06/06
07:05 – Arrived on site. Train 2 fill malfunction alarm sounded at 6:57.
13:00 – Increase injection to 8#/MMacf

2/07/06
07:15 – Arrived on site
15:00 – Noticed that there is carbon coming out of the rotary valve. Travis is ordering new bushings.
% removal about 80%

2/08/06
0730 – CS & BH on site.
1100 – Did overboard calibrations on inlet and outlet, both were well within the 20 % range.
1200 – Fixed the leak on train # 1 rotary valve by tightening the packing gland. I believe the packing will still need to be replaced at some point.
1400 – The d.p. at ESP inlet (across probe) still high (~130" H2O). Replace filter.
1700 – The entire ESP inlet sample equipment has been cleaned/replaced. D.P. now at ~30" H2O.
1800 – Left site.

2/09/06

0715 – BH on site. Train #1 has a "Eductor Suction Pressure Low" alarm. Train #2's pressures are 6.5 PSIG (blower discharge) & -1.0" H2O @ eductor, train # 1's pressures are 10.5 PSIG (blower discharge) & -1.5" H2O. The first alarm was at 1:45 AM and the second was at 5:40 AM. Current feed rate on train # 1 is 102 lbs/hr.

0740 – Boiler load currently at ~885 MW and steady since ~0620.

0900 – Boiler load down to ~450 MW

1430 – Eductor pressure alarm has alarmed several more times today. Closed down gate valve at eductor to increase pressure to -2.5" H2O.

1640 – Train # 1 Eductor Pressure low again. A large cloud of carbon could be seen coming from the screw outlet. Will shutdown train #1 as per Travis S. and Dave M. I am also stopping Train # 2. Will switch hoses so that train # 2 will feed the center of the ESP, closest to where we are sampling.

1650 – Train # 2 on, feeding center of ESP field 5, rate currently @ 71 lbs/hr (4 lbs/MMacf).

1706 – Carbon feed off. Carbon is leaking around fitting where it enters the ESP.

1830 – Disassembled the blower outlet (silencer?) on train # 1. It appears that there is a gasket missing that was causing the leak?

1845 – Will let EMCs run overnight with no carbon injection.

2/10/06

0715 – BH on site.

1000 – Removed silencer on blower # 1, one of the bolts is seized, the alignment pins are broken and there was no gasket.

1015 – Lowered pressure to solenoids on silo cones to 60 psi and 30 psi as per Travis S.

1035 – Carbon on through train # 1 @ 4 lbs/MMacf to centermost field five injection port. There was a loose pipe fitting that was causing the leak observed yesterday, after fixing that, no leak can be seen.

1130 – Plan to operate train 2 @ 4 lbs/MMacf until blower on train 1 is fixed. I discussed possible solutions with Cody W. We are going to try sealing the silencer back up with some sort of epoxy/silicone depending on what material can be found locally.

1510 – Train # 2 alarming at low eductor pressure now.

Carbon feed off, need to re-pressurize air system after pressurizing bag filter on silo.

1600 – Re- Zeroed the eductor photohelic, it was reading ~ + 2" H2O. Carbon on @ 4 lbs/MMacf trough train # 2, photohelic reading -2" H2O. The blower discharge pressure is at ~10 PSIG.

1640 – Carbon seems to be feeding well, but with the troubles experienced lately, will shut carbon off overnight just to be safe.

1700 – Left site.

2/11/06

0730 – BH on site. Train # 2 on @ 4 lbs/MMacf to field 5. Boiler load at ~560 MW. Blower discharge pressure @ ~ 10 PSIG, eductor vacuum @ ~ -3" H2O, draft control valve at eductor is 100% open.

1430 – Train #1 on at 4 lbs/macf. Drilled and taped the bad bolt on blower discharge. Was able to find new bolts locally. Blower discharge pressure @ 9.5 PSIG, eductor draft @ -1" H2O with control valve open 100%.

1630 – Silo trains running well. EMC's indicating ~ 80 % Hg removal. Leave site.

2/12/06

0800 – BH on site. Both trains are still running. There were two hopper fill malfunction alarms over night, both sides. The interruption must have been very brief because there was <u>no feed interruption</u>.
1030 – EMC running well, ran diagnostics, the desorb curve had gotten low (~1100 mv) overnight, but seemed to recover (~1500 mv) after blow back and calibration.
1100 – Downloaded data to ftp, trains running well, no alarms.
1130 – Left site.

2/13/06
0730 – BH on site. There were two train # 2 fill malfunction alarms early this morning (~0600). Neither caused a feed interruption. The test side BHA is not functioning properly. Will investigate.
1010 – BHA on line. The settings file was changed unintentionally during a data download attempt the other day. The settings have been restored.
1430 – The silo vent filter pulse valves are operational. The pulse valves may have been plugged with something that was causing them to stick open or simply frozen. I let the pulse valves cycle for a few minutes before turning on air pressure, not sure if this makes a difference or not.
1530 – Upload data to ftp.
1630 – Left site.

2/14/06
0700 – BH on site.
1100 – Have had Silo vent filter pulse air on all morning to clear filters out (hopefully). Turned off @ ~ 1100 hrs.
1430 – Upload data to ftp.
1600 – A package needs to be delivered to UPS for shipment to Dickerson. Leave site.

2/15/06
0700 – BH on site.
1500 – Upload data to ftp.
1530 – EZ on site.
1715 – BH and EZ leave site.

2/16/06
0807 – EZ on site.
1630 – EZ left site.

2/17/06
0820 – EZ on site.
1030 – Turned on the silo vent filter pulse valves in anticipation of a carbon delivery this afternoon. Waited a few minutes and then turned on the compressed air.
1100 – Turned off silo vent filters and compressed air. Alarm for low air pressure would repeat after alarm reset until I turned them off.

1230 – Notified that the sorbent truck might not arrive until 1700-1800.
1630 – Uploading data files to the FTP.
1730 – Carbon sorbent shipment arrives. Activate silo vent filter but keep getting alarms for low compressed air pressure. Then start getting alarms for high silo DP. Started at approx. 6800 lbs.
1835 – Done. Put in just about 35000 lbs, maybe just a little less but I called it off after it looked like it was just blowing around instead of going into the silo near the end of the refill (weight was not changing). Silo weight is now 40310 lbs. Stopped the silo vent filter thing.
1845 – I'm gone.

2/18/06
0837 – EZ on site.
EZ do some EMC stuff. Try to coordinate with the plant to increase the injection concentration to 10 lb/MMacf at a high load. Plant dropped load from 850 MW to 600 MW at 1000. Never went back to high load. Will try to coordinate tomorrow, if possible.
1500 – EZ leave site.

2/19/06
0815 – EZ on site. There were a few Train 2 Hopper Fill alarms at 1900 and 0200. Checked the trending log and noticed no decrease in sorbent injection.
0830-1215 – Both inlet and outlet analyzer chemicals froze in multiple locations yesterday evening and overnight. The analyzers finally started sampling a little after 1200. Removal was approx 78% (O2 corrected). That has been normal. Also looks like the plant has not increased to full load (> 750 MW) all day so far.
1730 – Upload data to the FTP site. EZ leave site.

2/20/06
0810 – EZ on site. Check out analyzers. EMC was flooded, hotline was full of chemical, two probes sucked in their impinger contents. Spent all day working on that, details in the analyzer log.
2045 – Analyzers are working again. No data download today because there's nothing to see. EZ leaving site.

2/21/06
0811 – EZ on site. Analyzers look okay. Removal is at 75% at high load 880 MW but there was some minor scrubbing at the inlet.
1100 – Internal project conference call.
1350 – Analyzer check OK.
1400 – External project conference call.
1415 – Upload data to FTP.
1600 – Analyzer check out OK.
1607 – Shut off Rotary Valves and Feeders of Train 1 and Train 2.
1615 – Shut off Blowers of Train 1 and Train 2. 26,350 lbs of Hg-LH in the silo.
1645 – EZ left site.

2/22/06
0845 – EZ on site. EMC looks good. Clean up site. Put EMC into safe idle mode for the 5-day break in testing.
1730 – EZ left site.

2/28/2005
0700 – CS and Kevin Fisher from Apogee on site
0800 – KF went to orientation

3/1/2006
0700 – arrived on site
10:04 – started first M17 test
15:05 – finished M17 test

3/2/2006
07:00 – arrived on site
08:45 – Plant switched to ColoWyo at ~22:00 last night. Contacted control room and found out that they won't switch back until late tomorrow evening or night.
13:00 – Starting injection at 10#/MMacf 5#/train
Train 2 fill malfunction alarm sounding every 10 minutes or so. Rapped on pantleg and it still sounds.
Turns out it is not the fill malfunction as I thought. It is a feeder malfunction. The feed screw motor is malfunctioning. Will look at it tomorrow. Turned of Train 2, increased train 1 injection to 10#/MMacf

3/3/2006
07:00 – arrived on site
11:00 – Started M17 test
15:35 – Finished M17 test
15:45 – Stopped carbon injection. Started to investigate the feeder problems on train 2
17:05 – Stopped problem test injection and hooked both trains back into the configuration we had yesterday. With train 2 going to the side away from the probes. If it trips over night we will still see removal.

3/4/2006
07:30 – Arrived on site. Last night train 2 tripped off at 7:11 pm. Will investigate further. Plant is still burning ColoWyo. Control room said PRB should hit the boiler later today or tonight.
10:09 – Train 2 feeder tripped again. Measured the DC output and analog in signals very noisy compared to T1. RPM fluctuating by ~15 on T2. Switched both trains to manual and set feed rate to 108#/hr. Measured voltage DC output signal and analog in and out signal now very stable.
11:54 – Dropped injection rate to 5#/MMacf until plant starts firing PRB.
17:00 – Contacted control room. PRB "should hit the boiler in ~3 hours increase injection back to 10#/MMacf

3/5/2006
07:30 – Arrived on site
13:00 – shut down carbon injection –
13:25 – hooked train 1 to pre-ESP system set injection rate to 1#/MMacf

3/6/2005
07:00 – arrived on site
10:10 – Removal rate appears steady ~73%. going to increase injection rate to 3#/MMacf
13:33 – Removal rate at 86% and rising
17:15 – Rough check of injection weight ~85%
17:25 – Increased injection to 6#/MMacf

3/7/2006
07:00 – Arrived on site Ian Clark and DM on site
07:36 – Increased injection to 10# acf. Removal rate held at 86% last night.
~09:45 – Started M17
~14:30 – Finished the M17 tests
14:29 – Stopped carbon injection, contacted control room to inform them the test was completed.

3/8/2006
07:00 – Arrived on site Ina Clark and DM on site
07:40 – Started injection in fields 5 and 7 at 3#/MMacf/side(6# total). Train 1 is going to the analyzer side. Train 2 is going to the right.
7:30 – Analyzer problems overnight – repairing.
8:25 – Analyzer repaired and calibrated, up and running.
11:30 – Train 2 started to act up again. Switched to manual 65#/hr
11:47 – Ian Clark and DM off site.
18:45 – Finished collected fly ash samples from the from row. Hopper B12 had hardly any ash in it. Checked with the control room they were running the O2 at –0.8%. No noticeable change in fly ash color.

3/9/2006
6:45 – Arrived on site
12:00 – Low load, low O2 test started O2 at 2.4% normal 3.2%= -0.8
noticed stack opacity is spiking at Field 7 raps. Also noticed that the train 2 feeder problem is happening as the cpm's see the field 7 rap at ~30 minutes after the hour.
16:06 – Collected samples from B-11 and B-12 Contacted control room to tell then that we are through testing at low O2 and load.
17:30 – Switched to field 5 from train 1 injecting 6#/MMacf. Going to watch the stack opacity to make sure it is going down.
19:20 – Changed configuration, hooked train 1 to analyzer side and train 2 to right side. Both set to 3#/MMacf

<u>3/10/2006</u>

06:30 – Arrived on site, Stack opacity back to normal
07:25 – Increased carbon injection rate to 12#/MMacf to empty silo. It's a carbon blowout!
17:15 – Shut down skid

APPENDIX C3: Independence Log Sheet—March 8, 2007

Independence Log Sheet

Thursday, January 11, 2007

- 0700 arrived on site (set up day 1)
- Observed that only one 4-inch PAC transfer line had been run and they used 4 of the 7 50 ft lengths of hose. This left only 3 for the next run I ordered more hose through Collin back in Denver. Also ordered a couple of more fittings for this hose. It my get here tomorrow or Monday at the latest.
- All the Contecos were delivered on site yesterday
- The plant hauled up all the equipment to the test area. (Slow start but worked very hard to get it competed.
- Hooked up the "Y" and the check valve to the new blower. Removed the old eductors and put together the new ones.
- Ran the Hot lines and sank the probes into the duct. Plugged in the EMC analyzer and have it just powered up.
- Filled all the chemical jugs with water
- Made a deficiency punch list for a run to Home Depot and Wal-Mart
- The plant did not have all of our equipment delivered to the trailer so it took some work to try and find it. At the end of the day it looks like everything that we had ordered was delivered and accounted for.
- Postponed a site meeting with Todd as the schedule for testing has not changed.
- The Load Request has been denied for the test period. There is cold weather coming this way and they expect to require full load around the clock next week.
- The Carbon was on site when we arrived this AM . Unfortunately it came in super-sacks and not bulk. The shipment was returned and bulk arranged for. The Carbon is expected to be here either tomorrow (Friday) or on Monday AM.
- Expected activities for tomorrow
    - Finish hooking up the new compressor to the new eductors and the splitters to the lances.
    - Run the blower to make sure that it does not trip after it runs for a while.
    - Hook up the electrical inter link or some other method to get the feeders to operate while the new blower is supplying the eductors.
    - Hook up most if not all the EMC equipment and start testing.
    - Build shelters around the probe equipment to prevent freezing.
- Left site at 18:30

Friday, January 12, 2007

- 0700 went shopping for materials to complete the setup Arrived on site (set up day 2). 0830
- Hooked up all the hoses and eductors on the skid
- Put together one of the 2 distribution headers the highest consumable next to carbon is Teflon Tape

- Put together approx ¾ of both the inlet and outlet test equipment. The outlet had problems with the filter heater. It had worked in Denver but decided that it wanted to short out once it got here.
- 18:30 off site

Saturday, January 13, 2007

- On site 0700 (set up day 3)(picked up a few more items from Home Depot)
- Got Inlet completely set-up by noon.
- Performed Leak check, calibrated and began sampling at 16:15
- Noticed a leak(O_2 = 17%) once sampling checked probe and found loose port cap. O_2 now at 6% and Hg corrected at ~6
- Brandon still having problems at outlet with heater. Got heater fixed just before we left. Had a short on the concave side somewhere. Used glass tape to cover it.
- 1900 left site for the day

Sunday, January 14, 2007

- 0700 on site (set up day 4)
- The inlet filter heater stayed hot all night.
- O830 started sampling at the inlet again after a calibration and a check out of the system
- Put together the remainder of the Outlet sampling equipment
- 1000 Inlet sampling. There is approx 1 ug removal across the ESP.
- Hooked up all the lances to the distribution headers.
- Each lance line was tapped for pressure measurements
- Hooked up the new blower discharge pressure to the silo motive air pressure gages and switches
- Tried to connect to the silo with the new computer – no luck so far. We may have to run the system on manual
- Turned on the air to silo – good pressure
- Removed the PAC drop tube on each silo feeder and taped them off in preparation for the carbon delivery tomorrow at 7 AM
- Still needing one more section of 4-inch hose to complete the PAC delivery system. This hopefully will be delivered on Monday AM.
- Checked out both STM boxes in preparation for tomorrows testing.
- 1630 left site

Monday, January 15, 2007

- 0630 floated into work (baseline day) to greet the carbon delivery
- Elevator out of service great way to start the day
- Rotary valves seized. One chain broken took couple of hours to get working.
- Ran dual STMs at in inlet and outlet.
- Attempted to collect hopper samples. Only able to collect hopper B11 even though Hoppers had been isolated for several hours
- Skid computer seems to be missing a RS Key. This is being sent out here tomorrow.
- Blower will not operate. Settings seen to not be configured properly.

- Analyzer working well. Seeing believable numbers compared to previous testing.
- Data looks a little spikey even with a side arm feed attached to flush out $SnCl_2$ impinger tube at both locations
- Blower operational. Cleared fault # 2021 with parameter 1608, needed to be set to "not sel".
- Downloaded EMC data
- 2030 left site

Tuesday, January 16, 2007

- 0700, day 6 begins (Parametric day 1), crew becoming weary, coffee pot non-operational
- Calibrate blower (target 11" h20 at ESP inlet), feed screws and EMC
- Blower settings: 22 amps, 30 hz, 75% of maximum, 4.4 psi at blower discharge.
- Recalibrate Silo screw as per Tom C.?
- Outlet probe thermocouple shot, replaced. Having difficulty keeping chemicals flowing due to extreme cold.
- Start carbon injection at 1 lb/MMacf (20 lbs/hr per feeder) @~1238 hrs (each M-Drive set at 40).
- Feeding manually due to no communication between computer and PLC. This requires a person to manually turn on star valve every 5 – 10 minutes.
- Carbon feeders backing up into the eductors, feed off.
- The CP20 was not set properly, the carbon was trying to feed at too high a rate.
- CP20's set to 800 each, start feed at target rate of 40 lbs/hr total at 1325 hrs!

Train 1				
Set Pt	**seconds**	**lbs**	**lb/ hr**	
100	120	2.92	87.6	
500	60	7.94	476.4	
1000	30	5.88	705.6	
2000	15	2.40	576.0	40
	CP 20 =	800.21		
Train 2				
Set Pt	**seconds**	**lbs**	**lb/ hr**	
100	120	3.30	99.0	
500	60	8.08	484.8	
1000	30	5.96	715.2	
2000	15	2.42	580.8	40.5
	CP 20 =	809.54		

- The silo calibration looks to be very 1:1 like in the lower ranges and falls away from this ratio at the higher settings.
- Silo load cells have indicated ~70 lb difference in the last ~hour or so, the scale read ~5620 @ 1425 hrs and 5550 @ 1525 hrs suggesting a total feed rate of ~ 70 lbs/hr. M-drive currently set @ 40 each train, we have been feeding at ~ 2 lbs/MMacf.
- Silo load cells indicating ~5502 lbs @ 1625, it was @ 5550 1 hour ago, suggesting a total feed rate of ~ 48 lbs/hr

- Have been feeding at current rate for 3 hours, increase blower, target 15" h2o at ESP inlet.
- 1630 hrs: Blower settings: 26.8 amps, 35.5 Hz, 88.7% of maximum, 4.8 psi at blower discharge.
- Silo scale reading 5450 lbs at 1725 hrs. 52 lbs/hr.
- Mercury removal same as at lower blower setting (~80%). Lower blower settings target ~8" h2o at ESP inlet
- 1730 hrs: Blower settings: 19.6 amps, 26.7 Hz, 66.8% of maximum, 3.7 psi at blower discharge. Lowered the blower pressures as we did not see any change in Hg removal when we had raised the pressures. Removal still remains at approx 80%
- 18:33 Shut down carbon feed after 1-hour test run. Did not observe any Hg removal. Hg removal was approx 76-80 % across the ESP. Left the blower running at the lower rate all night to keep the system warm and to keep the lances clean.
- 18:30: Chad and Brandon checking out the monitoring equipment for the night and downloading the analyzer data.
- Off site 19:30

Wednesday, January 17, 2007

- 0700 – Day 8 (Parametric testing day 2). Working to establish communication to PLC (need 30 foot serial cable and a serial card for the pc)
- Checked the feed rate before starting the set pt of 40 on the M-Drive with a CP of 800 actually fed at a rate of 29 lbs/hr which is equivalent to 1.5 lbs/MMacf injection concentration.
- The inlet Hg was reading approx 7 ug and the outlet was reading 5 ug this was more baseline removal than we have recently seen so we speculated that the filter may have been contaminated with carbon from yesterday's injection. After talking with Sharon, Brandon changed out the filter and the mercury readings remained the same.
- We wanted to start injection but the plant began to have operations problems with load swinging from 850 to 650 which showed up in the mercury analyzers as being very unstable. Decided to hold off injection until the unit stabilizes.
- Unit has not stabilized; evidently dispatch has been adjusting the power as required.
- Re-packed the gold in the EMC analyzer, inlet =~ 9 ug Hg, outlet = ~6 ug Hg.
- 1900 left site.

Thursday, January 18, 2007

- Start day 9 @ 0700 hrs.
- 0730 Checked all the analyzer equipment
- 0800 Calibrated the EMC
- 0902 Started Carbon injection at 1l b/MMacf or 20 lbs/hr on each feeder. M-drive CP values Train -1 = 700 Train - = 735 Blower at 30 Hz 21.2 amps and 4.1 PSI at the blower discharge. The outlet Hg had dropped after calibration which does not make a lot of sense because both inlet and outlet are on the same analyzer.
- 0900 setting up to run STMs

- 11:58 increased PAC feed rate to 3 lbs/MMacf. The transport air conditions remain the same as the 1 lb/MMacf injection concentration. Feeders are handling this rate very well.
- 12:00 Chad and Brandon started STMs at the inlet and outlet locations.
- 15:00 increase PAC feed rate to 6 lbs/MMacf (120 lbs/hr each feeder)
- Increase blower power to achieve ~11" h20 at ESP inlet lances. Blower settings: 23.3 amps, 33.0 Hz, 82.6% of maximum, 3.5 psi at blower discharge.
- 1555 hrs – control room called, they have to make some changes and it will affect load.
- 1700 – Load unaffected thus far, continue at 6 lbs/MMacf
- PAC is occasionally "lightly wafting" out of the end of the screw at the tee, have to shut screw off momentarily to wait to clear
- Hg removal just before we reduced injection rate was Inlet 9.03 Outlet .25 ug which represents 96.5% removal.
- 1702 – Decrease feed rate to 3 lbs/MMacf (60 lbs/hr per feeder) Blower settings: 23.3 amps, 33.0 Hz, 82.6% of maximum, 3.5 psi at blower discharge.
- Shut off Carbon injection at 1800 hrs. Downloaded EMC data, Plant data and loaded to ftp site
- 1830 hrs left site for the day.

Friday, January 19, 2007

- Started day at 0630 hrs
- Shut down everything in preparation for leaving the site.
- Chad will be the main contact for how and what the site requires to get running again.

Tuesday, January 23, 2007

- MAD arrived on site at 16:00 hrs
- Was able use hand carried laptop to see Silo PLC. Found that SLC battery is dead.
- Unable to clear fault.
- Departed site at 18:30

Wednesday, January 24, 2007

- CL and MAD arrived on site at 0730 hrs.
- Cleared fault on silo SLC.
- New battery ordered. Expect to have onsite Thursday
- Loaded RSLOGIX program onto SLC once fault cleared. Upon loading program communication silo. Had to establish communications via DH+ and change a setting in the software.
- Made changes to RSVIEW to allow connection to silo.
- Able to connect and control silo with RSVIEW
- Noticed potential clogging in lines or lances upon system startup. Was able to leave blower operating for a while and clear the lines.
- Breaker on blower #2 found to be tripping. Changed trip setting from 40 to 120A.
- Unable to connect to SLC w/ serial cable. Called Rockwell support no luck. Will call again Thursday and hope for better help.

- Analyzers up and measuring Hg at inlet and outlet. Will leave them up over night.
- Departed site at 19:30.

Thursday, January 25, 2007

- CL and MAD arrived on site at 0700 hrs.
- Began injecting carbon @ 1200. Load cells @ 4580.
- Stopped injection @ 14:20 due to persistent puffing problems. Attempted blowing out lances with HP air.
- Determined problems are resulting from restrictions in grid design (roughly 50% drop in cross sectional area).
- Communications problems with serial cable due to cable. Temp cable replaced with another temporary cable.
- Departed site at 19:00

Friday, January 26, 2007

- CL, MAD and JA on site at 0700 hrs.
- Began injecting carbon @ 1 lb/MMacf at 0930. Load cells @ 4480 lbs. Blower discharge @ 2.5 psi, Blower frequency, 30.0 Hz, 22.3 amps. Pressure at header 11.0 to 11.5 in H2O.
- Was able to get BHA CPM operational. Cleaned lenses on monitors.
- Changed injection rate to 3 lb/MMacf @ 1330. Silo load cells @ 4428 lbs. Blower settings unchanged.
- Plant started dropping load at 1400.
- Due to decreasing / varying load conditions skid placed in load following at 14:30
- Injection rate changed to 6 lb/MMacf at 1530. Blower settings unchanged.
- 1545 Changed blower settings to 26.2 Hz, 20.2 amps, blower discharge at 2.25 psi. Discharge header pressure @ 11 psi
- Unable to maintain injection rate on Train #2 (feeds side that the shack is over). Had to decrease feedrate on train #2 to 30 lbs/hr to prevent puffing problems. Train #1 remained in load following.
- Turned off injection system @ 18:30. Train #2 was able to maintain 30 lbs/hr without problems for the duration of this test. Train #1 was able to maintain up to 60 lbs/ hr during duration of this test without puffing issues.
- Noticed load ramping back up around 1700.
- Unable to get air flow readings due to hot wire anemometer getting fouled with carbon. BD will order new unit will for delivery early next week.
- Departed site at 2030.

Saturday, January 27, 2007

- JA on site at 07:00.
- Found Marty's ring at wash basin
- Cleaned up trailer.
- 19:30 Todd informed me that Boiler will be off line from 10:00 to 19:00 and that ASA will be on site at 15:00 tomorrow.
- Calibrated analyzers, downloaded data, shut down analyzers.

- Cleaned old impingers and installed new ones for next test.
- Copied EMC data to ftp site.
- 13:30 leave site.

Sunday, January 28, 2007

- JA on site at 09:30.
- Filled 3x5 gal DI containers at large green tanks.
- Worked on ASA Hardin Report.
- Printed new EMC Cal Sheets for Test Shack
- 14:00 ASA on site.
- 17:00 Sent Hardin Baseline data to Sharon.
- 17:30 Leave Site.

Monday, January 29, 2007

- JA on site at 07:00.
- Sent timesheet to Becky.
- Requested Unit 2 Isolate ESP Hoppers 1-2, 2-2, 1-3, 2-3, 1-4, 2-4.
- 08:30 Start first M5/202.
- 08:37 Blow back filter, Start up/Cal analyzers.
- 09:00 Analyzers on line, reading 6.5 Inlet and 6.0 ug/dscm Outlet.
- 13:30 Collected ash samples from 1-1, 1-2, 2-2. There was no ash in the back two fields and the sample port on 2-1 was plugged. I requested that the plant leave the back two fields isolated overnight.
- 14:50 Grabbed coal sample.
- Hg In = 6.0 and Hg Out = 6.0 ug/dscm.
- 15:38 End First M5/202.
- Post cal analyzers.
- Downloaded data to ftp site-CPM/EMC/Plant. Could not figure out how to do Skid Data
- 18:30 Gone (11.5 hrs)

Tuesday, January 30, 2007

- JA on site at 06:15.
- Requested Unit 2 Isolate ESP Hoppers 1-2, 2-2, 1-3, 2-3, 1-4, 2-4.
- 06:45 Start Second M5/202.
- 7:00 Found that fitting where impingers connect to probe filter at Outlet had melted and sealed the opening. Got old melted tubing out, but noticed someone had jammed other tubing into the gap between the filter and filter housing. Hope this doesn't affect reading. Replaced and did cal. Shortly after the tubing melted again. Reduced temperature from 400 to 350F. Noticed that temperature was swinging wildly. Removed TC from where it was installed and installed it into a filter port. Changed set point to 300F. Upon hooking up the impingers, the excess fluid flooded the chiller and some went into the heated hose. Luckily, the liquid did not make it past the Balston filter. Flushed hose with water, blew dry.
- Received battery for skid controller and 2 x 2.5 ml syringes and 6 x needles.

- Called Chad. Was able to get mouse working on skid computer by rebooting. Downloaded skid files and put on FTP site.
- 13:00 Collected coal sample. Tried to collect ash but all eight hoppers had strong vacuum and no ash. Todd said he would leave back two rows isolated tonight since they are done burning the ColoWyo coal.
- 13:36 End Second M5/202.
- Post cal analyzers.
- Downloaded data to ftp site-CPM/EMC/Plant.
- 15:15 Gone

Wednesday, January 31, 2007

- JA on site at 06:00.
- Back two fields of ESP Hoppers should have been isolated all night. Later, Todd informed me that these hoppers were not left isolated but will be tonight.
- 06:42 Start Third M5/202.
- 07:00 Outlet: Found another melted fitting at probe filter. Further investigation showed that the TC extension had a bad connection at the male end. When a new extension was used, the temp was above 450°F. Cut off the sealed male end and replaced it on the old extension.
- 8:45 Made new $SnCl_2$ and NaOH. Emptied waste. Calibrated.
- 13:20 End Third M5/202.
- 14:00 Collected coal sample. Got ash from, 1-1, 2-1, 1-2, 2-2.
- Post cal analyzers.
- Downloaded data to ftp site-CPM/EMC/Plant.
- 16:00 Gone (9 hrs) + 2 for Hardin at hotel.

Thursday, February 1, 2007

- JA on site at 06:00. Huge, historical, monstrous, news breaking, snowstorm last night (at least ¼") that brought Littlerock and surrounding communities to a complete standstill. Took me 1.5 hrs to drive 15 miles to hotel.
- Back two fields of ESP Hoppers should have been isolated all night.
- 07:05 Start Fourth M5/202.
- 07:00 Outlet: Everything running well, no melted fitting today!
- Hg In = 7.2 and Hg Out = 6.8 ug/dNcm. Calibrated. Emptied waste.
- All parts arrived to change splitter hoses from 1" to 1.5". Flour working on it.
- New anemometer probes arrived, but upon reading directions, it is obvious that this cannot be used in a dusty environment. Brandon is checking on more robust flow meter. Installed new microprocessor chip that came with new probe.
- 12:15 Found analyzer stuck on start-up screen. Turns out Flour tripped the transformer at about 11:30 and did not reset all breakers. Found the umbilical, kitty pad and probe heater off at the Outlet. Reset breakers.
- Hg In = 8.2 and Hg Out = 8.0 ug/dNcm.
- 13:00 Even with back fields off all night, only got ash from, 1-1, 2-1, 1-2, 2-2.
- 13:30 Collected coal sample.
- 13:42 End Fourth M5/202.

- Post cal analyzers. Blow back filters.
- Downloaded data to ftp site-CPM/EMC/Plant.
- 16:00 Gone

Friday, February 2, 2007

- JA on site at 06:00.
- Back two fields of ESP Hoppers should have been isolated all night.
- 07:00 Start Fifth M5/202.
- 07:10 All was well with EMC.
- Calibrated. Hg In = 8.2 and Hg Out = 8.1 ug/dNcm.
- 10:00 Activated carbon truck filled silo.
- 12:45 Collected coal sample.
- 13:00 Collected a little ash from, 2-3 and a full bottle from 1-3. All other hoppers were empty.
- Notified Unit 2 CR that they could return to normal operation on the ESP.
- 13:36 End Fifth and final M5/202.
- Post cal analyzers. Blow back filters. Shut down EMC system until Sunday.
- Downloaded data to ftp site-CPM/EMC/Plant.
- 15:00 Gone

Sunday, February 4, 2007

- JA on site at 10:00. Super Bowl Sunday!
- Installed new impingers, repositioned peristaltic pump tubing, blow back filters, calibrated.
- 13:30 Gone

Monday, February 5, 2007

- BH, CS & JA on site @ 0715
- Calibrated analyzers
- Noticed load on silo computer differs from pi system silo reads 844 pi reads 806
- Ran calibrations @ 500, 250 and 100 on M-Drive, all settings are ~ 14% low, lowered the CP20 value by ~ 14% each feeder. Spot checked each feeder, train # 1 OK, train number two still low, decrease CP20:
- Train # 1 CP20=610
- Train # 2 CP20=575
- Silo wt =43537 (@~1200 hrs)
- ~1300 start carbon
- ~1301 mouse on silo computer locked up, reboot computer
- ~1315 carbon on manually @ ~ 30lbs/hr
- 1326 switch to auto mode (RSView)
- Blower: 30.6 Hz, 19.6 Amps
- 15:49 – shut off feeders

- 1945 – Finish blowing out every injection lance we could reach (20 total), many of them were plugged or partially plugged. Keep blower going overnight but did not restart carbon. Going home now. (12.5 hrs)

Tuesday, February 6, 2007

- CS, BH on site.
- Finish blowing out four remaining PAC lances.
- 09:30 - 43680 lb in silo
- ~1030 – start injection @ 2 lbs/MMacf
- 10:33 silo wt = 43640
- 11:03 silo wt = 43869
- making carbon as we remove mercury
- 11:20 – Increase percent open on vent valve at blower discharge to decrease pressure at PAC injection manifold. (~16" H2O to ~12" H2O)
- 11:56 – 43820
- 12:28 – 43863
- 13:30 – 43869 – Checking for loose/bad wires on load cells and junction box
- Found some moisture in the load cell wire junction box, seems to be OK now – Reset totalizer 13:45 hrs
- 44056 @ 13:47
- 43999 @ 14:00
- Have installed ¼" pressure taps on all 24 injection lances, doing a traverse now
- 17:00 – Carbon feed off. It is thought by many that one or both manifolds are still partly plugged. Silo weight = 43965
- installed pressure taps on all 24 lance hoses. Pressure on west side (edge) 12" h2o, pressure on east side (center of ESP) =10" h2o
- check east manifold for clogs- none found
- blowing back all lances with 1" high pressure line. Will check pressures to see if both sides are equal pressure
- 18:45 restarted feeders still at 2#/MMacf
- silo weight =43953 @18:49
- 1945 - Leave

Wednesday, February 7, 2007

- BH & CS on site.
- 07:30 Silo weight = 43720, no alarms overnight
- 10:30 - stopped feeders to work on eductors on train 1 – no noticeable difference
- 10:30 silo wt = 43100
- 11:30 - adjusted pressures on train 2 to 11"
- 13:50 – increased blower rate to 4#/MMacf unit at full load
- 14:34 – silo wt = 43400 gaining wt again
- 17:39 – Feed off to check feeder calibration
- 18:02 – Carbon feed on
- Train # 1 = 40.8 lbs/hr

- Train # 2 = 40.2 lbs/hr
- 1900 – Leave

Thursday, February 8, 2007

- BH & CS on site.
- Silo running well, a few low suction pressure alarms on train # 1
- Average Hg removal = 86.5% since feeding @ 4#/MMacf
- 1015 – Increase carbon to 5#/MMacf
- checked injection rate at 60 lb/hr= 6#/MMacf @ full load
    - Train 1 = 60.0#/hr
    - Train 2 = 61.2#/hr
- 1435 – Increased carbon to 6#/MMacf
- 1540 – Increase blower pressure to manifolds
- 1840 – Left Site

Friday, February 9, 2007

- BH & CS on site.
- Plant switched to ColoWyo coal @ ~2000 – 2030 hrs last night
- 0930 – ColoWyo coal expected to run out any time now
- Over night the inlet SNCl2 feed stopped dropping the level to near zero. Got it back on line and noticed there must have been a coal change as well.
- 10:50 Carbon on train one was interrupted briefly.
- 13:15 Carbon on train one was interrupted briefly.
- Readjust blower pressure to achieve 11" h2o at PAC injection points, (was ~10")
- Started set up for STM testing.
- 1845 – Left Site

Saturday, February 10, 2007

- BH & CS on site.
- ~07:30 Carbon is "puffing" out of both feed screw trains. Feed off.
- Pressure now higher on East side train 2
- 1040 – Blew out all 24 injection lances with high pressure air, two may have been plugged (1B & 1C)
- 1042 – Start carbon @ 5#/MMacf
- 16:36 – Stopped carbon feeder on both trains
- 19:23 – Start carbon @ 5#/MMacf

Sunday, February 11, 2007

- Arrived on site to find carbon puffing again on train two east side
- Checked pressures upstairs and pressures are ~ 9 on east side and 8 on west
- Went upstairs to find mercury levels very low again. Called control room and found they started burning ColoWyo at ~18:30 last night and rat-holed this morning at 8:40. Should see north antelope in ~4hrs.
- Stopped carbon feed at 09:51

- Switched Train 1 line (west) with Train 2 line(east). The east side had been higher pressure. The east side still has higher pressures. Blew out lances on east side now both pressures are approx equal. Both sides are approx 12 w/o carbon.
- Started carbon at 15:50 @ 5#/MMacf.

Monday, February 12, 2007

- 6:30 - TC, EZ on site
- 7:15 Talk with Gary Goldblum of ASA. He will be beginning M-5 test in the stack as soon as he gets up there. Talked with Todd Bradberry of ISES. Load will be running until approx 2-3 pm. ColoWyo trains not scheduled to return for several days. So should see good Hg numbers for testing.
- No immediate evidence of puffing but Train 2 has minimal negative suction pressure. Silo weight changed 1100 lb over 12 hrs. Slightly lower loads for part of the 12 hrs but appears to indicate little or no free flow conditions.
- 10:15 First puff of the day. Stopped of its own accord.
- 11:58 Second puff. And stopped 15 seconds later.
- 14:05 Secure M-5 testing – Complete. Inform control room we are off load requirements.
- 14:47 Two puffs.
- 15:05 Both trains puffing slightly. Load is down at 630 MW
- 15:09 Secure both feeders. Still some back pressure on the system as continue to bleed carbon slightly. Dies off. Load continues to drop. Shut bleed off valve and system back pressure pushes carbon out of hose. Open bleed off valve entirely and slight leakage that dissipates. Go up and blow out hoses – 4 plugged lances.
- 16:17 Start feeding carbon at desired rate. Load is now 797 MW.
- Silo and EMC appear to be running fine.
- 17:05 Depart site.

Tuesday, February 13, 2007

- 0630 – TC, EZ on site. Unit not yet at load. Waiting for load stabilization prior to testing.
- 0645 – ASA checks in. Will wait for call from us.
- 0710 Load stabilizes at 880 MW. Talk to ASA, testing will start at 0810.
- Talk with Todd Bradberry. He has isolated all rows in ESP B except row 1. All rows will be blown down at 1200. Row 2 will be isolated every day at 0800. Row 3 and 4 will be isolated except at 1200. Soot blowing will run during this week for M-5 testing in the P4 mode, similar to baseline conditions. Monday's testing had a different configuration for soot blowing. ESP is operating with POS in normal load following mode.
- Check lances at 0800. 4 lances were plugged. Banging on lances had pressure to lances again.
- Train 1 did puff this morning at lower load. Based on alarms, puffed twice through the night. Does not appear to directly correlate to upswings on load. Both puffs occurred during load increases but not all load increases result in an alarm condition. Further monitoring will be needed.

- 0831 Began closing bleed off valve. Ate some carbon. Cannot get above 2 psi discharge pressure without beginning to backpressure system. Brian reports used to run at 5 psi blower discharge pressure. Lances cannot be fully open. Further mechanical agitation will be needed.
- Computer locked up. Rebooted. Now the RSView display is not showing the correct colors, but everything appears to be running correctly.
- The train 1 hopper had problems filling for some reason. Air is really moist, wonder if problems due to humidity in system, both carbon and electronics.
- Took ash samples. Will be done at 1447 with M-5 testing. Ash samples came from hoppers 1-1, 1-2, 2-1, 2-2, 3-1. Nothing from hoppers in row 4 and hopper 3-4. Plant isolated row 3 and 4 at 0930 and will keep isolated until 12pm tomorrow. Only reason we got something from 3-1 is a rap cycle on the carbon. Good timing.
- Check lances. Injection pressure upstream of manifold now at 5in. 2 plugged lances. Tap on all lances and 2 plugged lances clear.
- Talk with AA and reschedule M5 testing to occur at control and test side of outlet duct on ESP B. This is a change from previous test location which occurred at stack.
- 1730 Depart site.

Wednesday, February 14, 2007

- 0645 TC, EZ on site. Begin daily routine.
- 0800 Talk with Don Young at plant concerning rescheduling of plant load for Sat-Mon. Last weekend unit was loaded up so Don thinks there should not be an issue. Todd Bradberry is gone for the week, departed Wed noon, so Don is the contact through end of day Thursday. Friday and the weekend we are on our own.
- Silo has puffed once this morning. No work done on clearing lances.
- Something new learned every day. When some of the RSView colors are not working but the data on the screen (numbers, etc.) are updating, the daily file is not being updated. Data for silo not captured from 0830-13 Feb to 1030-14 Feb. Program rebooted at 1030.
- 1145 Sampled ash: 1-2, 2-2, 3-1. All other back hoppers empty.
- 1400 Rapped on all the lances and took pressures. 4 lances plugged. – cleared after rapping.
- 1430 Blew out all lances with high pressure air.
- The high pressure air seems to work better as the pressure upstream of the manifold dropped by 1-1.5 in (from 7 to 5.5 in) and did not change while rapping the lances. This would seem to indicate that the lances cleaned out better during high pressure cleaning than rapping. It could also indicate that we have lost some lances since the manifold pressure is dropping and removal rates are decreasing. However, we have been unable to increase air supply, so maybe that is not the case. Could just be gradual build up of carbon in the system or ash on the lance exterior at the holes which is causing increased back pressure and therefore lower flows, less penetration, etc.
- 1730 Downloading CPM data
- 1840 Depart site

Thursday, February 15, 2007

- 0630 TC, EZ on site. Unable to confirm availability of load for weekend.
- 0700 Talk with Gary Goldblum, ASA, about testing sequence. Decision is made to use 2 9 ft probes on control and test sides to do a comparison. Initial set up was a 9 ft on test side and 5 ft on control side but Gary thinks he has equipment to use two 9 ft probes. ASA also having a problem with icing. Temperature will remain below freezing for much of the day, so could be a continuous issue.
- 0830 Appears we may have a heater problem on the inlet probe. Will continue to investigate. Pulled cover off probe and heater started working. This is not the same heater that had problems previously. Should get a spare on site if/when it fails.
- 1000 ASA continues to have problems with freezing lines, waiting start of testing today.
- 1100 ASA begins sampling for the day.
- 1140 Sampled ash: 3-1. All other back hoppers empty.
- 1625 RSView computer locked up again. Second time today.
- 1632 Secured feed system
- 1638 Identified problem with inlet heater. EZ found a loose wire. There is a spare heater on site. Will replace in the morning.
- 1815 Replaced eductors and started blowers.
- 1820 Start injection. Looks OK.
- 1835 Depart

Friday, February 16, 2007

- 0645 EZ, TC on site. Silo is back pressuring and causing a cloud. Looking at alarms, appears to have started at approximately 0615.
- 0657 Secure feeders. Bang on lances. Injection pressures after clearing all lances is 11” east, 14 in west. This is original pressures for lance design. Adjust air flow down slightly. #2 Train is still back pressuring slightly. Will clean out after Method 5 testing.
- 0745 Begin feeders on Train #1. Train #2 is back pressuring still when feeding.
- 0755 Start Train #2 at 1 lb/MMacf, begin to walk up to 5 lb/MMacf.
- Eductors are definitely driving negative now, too low a flow and eductor will not pull enough negative, below approx 2 psi at eductor inlet.
- 0805 At 5 lb/MMacf.
- Shift from 4 hr rap to ½ rap appears to have eliminated spikes. ASA is struggling to get Method 5 underway.
- 1015 So much for the new eductor. Train #2 had a spit up. Secured feeding on Train #2. Will check pressures upstairs to see if I can lower manifold pressure.
- 1051 Started Train #2 after blowing it out. Still running a significantly higher pressure upstream of the manifold. Cleared out two potential blocked lances – 1A and 4C. This back pressure is translating into less negative and therefore more likely to blow back. I do not suspect free flow conditions, just back pressure conditions.
- 1107 Train #2 off again.
- 1405 Train 1 puffs. Back on line again.
- 1435 Train 1 off for back pressure

- 1540 Cleaned out injection lances with high pressure air. Have negative on both trains. Will continue to run with just air blowing through lances.
- 1559 Started carbon injection at 2.0 lb/MMacf on both trains.
- 1645 Lower injection concentration to 2.5 lb/MMacf for the night. That way if it upchucks, we'll only have to clean half the mess.
- 1700 Depart.

Saturday, February 17, 2007

- 0645 EZ, TC on site. Several alarms through the night but no big pile of carbon on the deck. Increase injection rate to 5 lb/MMacf.
- 0730 ASA begin Method 5/202.
- 0750 Stopped Train #2. The wind is blowing so hard it is messing with the little negative available. Will clean out train #2 and restart.
- 0910 Train #2 cleaned out.
- 0943 Lowered injection concentration and started Train #2. Will slowly bring up system. Still very windy out.
- 1005 Train #2 off again. Cannot hold it in the wind.
- 1139 Sample hoppers. Hopper 3-1 is only good sample. A smidgen out of 3-4 and nothing from 4-1, 4-4.
- 1345 ASA done with Method 5 tests for the day.
- Train #2 off line for rest of day.
- Run through STM procedures, begin STM traps in Method 5 port at 1830.
- EMC had a hard day. Taken apart and cleaned through the day.
- 1930 TC departs site
- 2100 EZ departs site after completion of STM traps.

Sunday, February 18, 2007

- 0645 EZ, TC on site. Train #1 online. Several low pressure alarms through the night indicated continued puffing. Train #2 offline. Walk down lances – 7A and 7B are plugged as usual. Doesn't take much tapping to clear lines. For some reason Unit 1 is off-line. Not many people around so doesn't appear to be a scheduled outage.
- 0715 ASA commences Method 5/202.
- Cannot find the data sheet for the skid and blower that we have been updating. Lost the last week of data. EZ found it by crashing Excel
- 1325 ASA completes Method 5/202.
- 1327 Plant begin shifting load around.
- Begin cleaning up and preparing for turn over.
- Depart site at 1700.

Monday, February 19, 2007

- 0645 EZ, TC, BD, CL on site. Train #1 online. Several low pressure alarms through the night. Train #1 still running. Train #2 down.
- Tried to clear out the lances with HP air on the west part of the ESP. Could not do this with the existing Poly tubing as it was getting to soft due to the heat. Copper tubing was decided against because of it being too good of a conductor in case the

lances had come apart. Ordered appropriate PFA tubing from Denver to do this. It should arrive tomorrow.

- At about 3 pm noticed the carbon feed to train 1 had stopped. Somehow the blower running signal stopped. It took a few tries before the PLC would allow me to control
- 1500 hrs Charles noticed that the outlet impingers had turned to crystals in the NaOH. Charles found that the chemical pump had been turned off. Suspect it ran this way all the previous night.
- 1530 hrs the EMC decided to freeze up. Charles had to use the hyperlink to delete the files and restart the system
- I was playing with the blower and the lance system after ASA had completed the testing. I had the eductor pressure up to 8 PSI with no puffing but the back pressure upstairs pegged the magnahelic.
- 1830 hrs left site

Tuesday, February 20, 2007

- Brian and Charles on site until the 27th.
- On site 0700 hrs
- Shut down carbon feed to train 1 to bang on lances and to reposition some of the hoses from the splitter to the lances
- 0720 Charles doing a cal on the analyzers found a high cell pressure on the outlet analyzer suspect that some crystals from yesterday have plugged the system. Charles continues to investigate and to start to prepare for moving the probe to a new port.
- Ran train 1 eductor at 4.5 psi (eductor inlet pressure) all night there was only a small point in the night around 11 pm that the eductor pressure showed a low alarm signal. There was no mess on the ground in the morning so it appeared that the alarms were brief and corrected quickly.
- 0850 started PAC feed to train-1 again. Plant at low load since we had come in 633 MW
- 1100 took ash samples - also took a coal sample
- Moved the outlet probe two ports East or port #4 from the western most port this is the port that ASA had been testing in.
- Both analyzers running but developing some high cell pressures. Suspect a plugged chiller ran some water to it and it improved somewhat. Will investigate more tomorrow.
- 1600 Left site for the day 10 hrs

Wednesday, February 21, 2007

- Arrived on site 0715
- Carbon had been puffing for quite some time last night so there was quite a mess this AM. Plant on low load.
- Shut down PAC feed from 0730 to 0900 banged on lances took some pressure reading. The east duct had a pressure of 14 inch at the inlet to the splitter and all the lances varied between 12.5 and 13 inches (east grid only).
- 0900 restarted injection of PAC to the east grid. Could only run at 2.5 inch H20 on the inlet pressure to the eductor.

- 10:00 Shut down PAC injection to clean the lances
- We had notice that the analyzer was still having high cell pressures and in fact the sample flow was severely reduced. Charles found that the gold had been compacted to a point that it would no longer allow a flow. Replace and repositioned the gold. This solved the flow problem at the analyzer but the chillers still severely restricted the flow. It looks as though the chiller caused the problem in the first place which caused a huge draw against the gold. Charles working on unplugging the chiller at both the inlet and outlet. Suspect some hydroxide crystals forming to cause this problem
- Cleaned out all the lances with the 3/8-inch PFA tubing 60 ft in length and HP air. All the lances were cleaned to the bottom. Most had plugging up to 4 ft from the bottom of the lances. I do not think that putting HP air to the lance will clear anything that is in the bottom of the lances. This may be effective in clearing the exposed holes. Based on this observation on the extent of the plugging I concluded that we were only using about ½ the holes in each lance. Prior to shutting the injection system down we were running at approx 2 PSI eductor inlet pressure approx 0 on the eductor suction the pressure on the splitter was 14 inches of H_2O and the pressure on the lances ranged from 12.8 to 13 inches. This sort of confirms my thought that half the holes were plugged.
- After the lances were cleaned I again took the opportunity to reposition some of the hoses from the splitter to the lances in an attempt to make the flow a little easier.
- Restarted the transport air to the east injection grid. It was more than obvious that the lance restrictions had been removed. I could have run the eductor motive pressure to 12 inches and still had lots of eductor suction to play with. What I did settle on was an eductor pressure of 7 PSI and an eductor suction of 0.5 inches. The pressure on the distribution was too high to measure and so was the pressure on the lances.
- Installed data recorder on the control side CPM
- My way of thinking on this system is that we have to target the desired air flow instead of the back pressure because of the need to maintain enough flow to transport the PAC to the lances. If the pressure at each nozzle is too high the plume will penetrate further in. If this is how we have to run the system then all we have to do is change the angle of the nozzle to allow for this difference in plume penetration.
- 17:50 started PAC injection at 2 lbs/MMacf to see how the system would handle running at these conditions. I nervously left it at this rate over night.
- 18:40 left site

Thursday, February 22, 2007

- 0715 sped into the plant to see if we had produced a cloud of PAC to equal the plume of steam coming from the stack
- Found the system in exactly the state we left it in.7 PSI eductor inlet pressure .5 inches eductor vacuum. There were no skid alarms all night.
- Checked out the entire system . The Hg removal was:

  Inlet 10.02
  Outlet 2.06
  Removal 74.21 at 2 lbs/MMacf
- 0745 increased injection concentration from 2 lbs/MMacf to 3 lbs/MMacf.

- 0900 Charles went to download the EMC data and found that the analyzer had locked up again. Charles will unhook the impingers and reset the computer. We suspect that there are corrupt sectors on the hard drive that will continue to plague us. It may come down to doing a "fix disk" dos command to repair this but we will loose everything on the hard drive. The "A" drive floppy will not read so this again is causing more problems. Charles swapped out the computer from the spare analyzer. We will try to get the data from this computer when we have sufficient time.
- 1130 tried to get ash samples but there were none to be had..
- 16:30 the inlet analyzer started to read 21% O2 found a few things wrong with the system once we started to investigate. It leak checked OK so we assumed it was the filter. Found a nylon cap on one of the filter ports and the filter connection to the inertial filter loop was very loose. This did not solve the problem Sharon suggested that it may be the blower. She was right. – again.
- Changed out the blower on the inlet probe an the union fittings were not the same on each blower. I did not know that we had different connections.
- Once the blower was changed we were getting very low Hg readings at both the inlet and outlet. Called the control room and found that they were burning ColoWyo coal. The expected to continue to burn this coal for another 4 to 5 hrs.
- 1930 left site.

Friday, February 23, 2007

- 0715 on site
- 0715 found the blower had tripped out at 0530 hrs Lost Power to the welding outlet. Contacted the maintenance supervisor for repairs and he indicated that it would take a while as the entire plant is having a safety meeting. While I was waiting on the electrician I inspected the blower and found that the air intake filter had collapsed. This was most likely the problem– I remove the filter and blew it clean with HP air. There was a super-sack worth of carbon in it. The filter number is 810475 (universal) or 2358 (Napa). Blew out the entire blower containment box.
- 0715 found that the EMC analyzer was not sampling at the outlet location all night. Charles was positive that a check to see if both channels were operating last night was the last thing he had done.
- 0830 Charles found that the inlet analyzer filter heater had tripped off. The plug was covering the GFI trip button so it actually looked like it was not tripped.
- 0920 electrician restored power and I restarted the blower.
- 0940 started carbon feed at 1 lb/MMacf blower and eductor conditions are:

  Eductor inlet pressure 7.2 PSI
  Eductor suction -0.2 inches
  34.4 Hz
  39.2 amps
  86.1 %

- 0950 increased PAC feed to 3 lbs/MMacf the blower and eductor conditions are:

  Eductor inlet pressure 7.2 PSI
  Eductor suction -0.2 inches
  34.4 Hz
  39.0 amps
  86.1 %

- 10:30 Hg removal rate at approx 65%
- 13:30 increased Pack injection concentration to 5 lbs/MMacf the blower and eductor conditions are:

  Eductor inlet pressure 6.9 PSI
  Eductor suction -0.2 inches
  34.3Hz
  37.9 amps
  85.8 %
- After one hr at this increase carbon injection rate the Hg removal is unchanged.
- 13:45 tried to take ash samples could not get any from the last two rows. All the hoppers were drawing very strong vacuums. Coal sample taken.
- Purchased a new floppy and disks to try to recover the data on the EMC computer This did not work. Something on this EMC computer is not letting it communicate.
- 17:15 Hg removal is approx. 74% at 5#/MMacf
- 18:45 left site (11.5 hrs)

Saturday, February 24, 2007

- On site 0700
- Noticed that the injection grid had a few alarms of low eductor suction for a 2 minute period last night at approx 9:12 pm The system looks just like we left it the previous night.
- 07:30 the Hg removal is 81% at a injection concentration of 5 lbs/MMacf ant the load at 700 MW
- The EMC's were primed for disaster. (This means that every thing looked good for now.)
- Charles calibrating and downloading data.
- Hg removal was 81% MW =700
- The weather was terrible so we took some time to cover the electrical transformers upstairs. This proved to be a good move once the wind changed direction
- 10:00 Shut off PAC Feed to take flow measurements
- Picked up new blower air filter.
- Was able to get 2 complete sets of flow measurements before the wind and rain changed direction. The rain was pouring directly down on the silo and blower area making it impossible to work with the hot wire.
- 1510 Tried to restart PAC feed on train 1 but the M-drive control was going crazy found that the door on the Silo cabinet was not tight and rain must have gotten in.
- I switched the lines for the PAC feed to train 2 and used this side to feed the east grid. This worked. I also installed an air line into the skid cabinet to bleed dry air into the system. After about an hour of this the Train-1 m-drive decided to start working again.
- 16:10 PAC feed on train 2 stable and we plant to leave the feed on to the East grid on train-2 all night. Decided to watch this for a while before leaving site.
- 17:30 left site

Sunday, February 25, 2007

- 07:15 On site
- 0715 found this computer locked up. Had to do a hard boot and unfortunately we lost some of the log entries from yesterday. I had written some of them down on paper and gave the best description as to yesterday series of events that I could recall. This document was scheduled to be saved every 5 minutes but it appears that the save feature was not doing this at this interval. I changed the save to every one min. tested this and it appears it does not save.
- Injection grid ran without an alarm all night.
- 0800 Hg removal at 78% @ 5 lb/MMacf MW = 750
- Blower settings are:
  34.7 Hz
  37.2 amps
  86.7 % power
  Eductor inlet Pressure 6.7 PSI
  Eductor suction -0.3 inches H2o
- 11:15 shutting down PAC injection to install the old eductor to the new blower system and the old 2.5-inch line. Modified all the components to accommodate this change.
- Tried to get ash samples from Hoppers 31, 34, 41, 44 and could not get any. I have had these hoppers isolated for days.
- The current Hg removal rate is 74% MW = 890
- 15:49 Started PAC injection at 5#/MMacf on the old eductor with the new blower.
- 17:30 left site for the day.

Monday February 26, 2007

- 0715 BD CL arrived on site.
- Found the PAC injection system down. The alarms indicated that it went down about 730 last night. Found that the breaker had tripped for the blower
- 0735 PAC system up and running again.
- 0745 found that the EMC vacuum pump had stopped overnight. This in turn caused the chemicals to snurfed from that moment on.
- Cleaned both inlet and outlet probe filters
- 14:10 Started sampling on the outlet
- 14:30 Started sampling at the inlet location
- 15:00 Hg removal at 84% at 5#/MMacf
- 15:30 got an ash sample from only one hopper in the third row. Hopper 33 all the rest were empty. Took a Coal sample
- 15:30 calibrated the analyzer and downloaded data.
- 17:30 hrs left site 10.5 hrs

Tuesday February 27, 2007

- 0720 BH CS BD CL all on site.
- Both inlet and outlet Hg readings are low so the plant is probably burning ColoWyo coal.

- Attempt to collect ash from 3-1, 3-4, 4-1 & 4-4. Hoppers have been isolated all morning, no sample obtained. The plant needs to put those two rows back into service as they may be changing coal soon. Did collect a sample from hopper 3-3 just for fun.
- Shipping 1L ash samples and coal back to Denver
- Have 6 5 gallon buckets of ash
  - 3 from silo #2 that contains North Antelope ash w/o carbon
  - 3 from silo #1 that contains North Antelope ash w/ carbon. The samples contain ash from the test and control side from field 3 and 4. So ~50% of the ash in the bucket is from the control side.

Wednesday February 28, 2007

- 09:48 – Stopped feeder to take a quick grab sample to check the feeder calibration
  - 2 checks averaged 46 lb/hr
- Started carbon back up at 10:04
- Hg removal across the ESP was ~ 76 % upon arrival this morning. This after ~24 hours of feeding carbon at 5 #/MMacf in the current eductor/lance configuration (train #1 via the old eductor to the new blower system and the old 2.5 inch line).
- Hg removal was as high as 84% when this configuration was initially started.
- Chad is currently analyzing the rest of the data from this time frame to determine if the lower removal rate has been a steady decrease, or if the initial 84% removal rate was just a high reading.
- The pressure of the blower outlet has decreased (to ~ 8.5" H_2O) since yesterday, increase blower setting slightly. Current settings:

  37 Hz
  46.8 amps
  79.9 % power
  Blower outlet pressure = 9 psig
  Eductor inlet Pressure 9 PSI
  Eductor suction -0.5 inches H_2O

  Yesterday @ 1600 hrs:
  31 Hz
  46 amps
  77 % power
  Blower outlet pressure = 10 psig
  Eductor inlet Pressure 9 PSI
  Eductor suction -0.5 inches H2o
- The decrease in the blower outlet pressure could be an indication that there is no restriction in the PAC line or lance grid, the blower outlet bypass valve is and has been completely closed for some time now. The pressure at the injection lances have all been a consistent 8 to 9 inches of water since yesterday.
- Blew out all 12 injection lances, have not yet observed any change in removal.
- Row 3 and 4 ash hoppers have been isolated all day.

- 1510 - Attempt to collect ash from 3-1, 3-4, 4-1 & 4-4. Hoppers have been isolated all morning, no sample obtained. The plant needs to put those two rows back into service as they may be changing coal soon. Did collect a sample from hopper 3-3 just for fun.
- Blew out all 12 injection laces with high pressure air, most seemed to have solids built up in the lance(1-6 ft). The pressure at the lance inlet now down to ~ 2 to 3 inches of water. This suggests that the carbon is probably only dribbling into the duct which would account for the 70% removal we are seeing.
- 1814 – carbon off to clear out any carbon build up within the line. Depart site.

Thursday March 1, 2007

- 0720, BH & CS on site. The log computer locked up this morning, had to re-enter the last bit of log entries from yesterday.

Current Conditions:

32 Hz
45.8 amps
79.9 % power
Blower outlet pressure 8 psig
Eductor inlet Pressure 9 PSI
Eductor suction -1.8 inches H_2O

- 08:30 checked pressures on lances. All still at 2-3"h20. Rodded out lance 5C , which had the most amount of carbon in it last night. It was clear. Also checked the line to 7A to check for clog, none found
- 09:00 – Switched to 4" line on East side. Opened up bleed valve and hooked the hose to Train 2(near cabinet).

Current Conditions:

32 Hz
41.9 amps
79.9 % power
Blower outlet pressure 7.5 psig
Eductor inlet Pressure 8 PSI
Eductor suction -0.8 inches H_2O
East manifold pressure = ~ 34" H_2O

- 1015 – Start carbon on train # 2 to East manifold at 2.5 lbs/MMacf (~26 lbs/hr).
- 1025 – Increase carbon to 5 lbs/MMacf (~26 lbs/hr).

Current Conditions:

32 Hz
41.9 amps
79.9 % power
Blower outlet pressure 7 psig
Eductor inlet pressure 7.5 PSI
Eductor suction inches -1 H_2O
East manifold pressure = ~"H_2O

- 1300 – Hg removal not getting any better than ~ 75 %. Switch EMC probe back to the west by one port (was in the fourth from the west, now it is in the third from the west).
- As of this morning, ash hoppers 3-1, 3-2, 3-4, 4-1, 4-2, 4-4 have all been bypassed since sometime last night.
- 1450 – Was able to collect a good ash sample from ash hopper # 3-1! That was the only one though.

  Note: Hoppers 3-3, 3-4, 4-3 and 4-4 were all "in service" after the sample was obtained. Evidently the operators are not able to maintain the hopper configurations they say they can.
- 1530 – Finish reinstalling the 4" feed line with the small eductor on train # 1. Currently it is hooked to the west manifold; the lances are being cleared of any residual carbon. (Carbon is <u>not on</u> to the west manifold, (train # 1)). Carbon feed to east manifold was temporarily interrupted due to low eductor pressure on train # 2.
- Continue carbon to east manifold (train #2) at 5 lbs/MMacf (50 lbs/hr).
- 1720 – start carbon on train # 1 to west manifold at 5 lbs/MMacf (50 lbs/hr).
  32 Hz
  38 amps
  79.9 % power
  Blower outlet pressure 7 psig
  Eductor inlet pressure 7.5 PSI
  Eductor suction inches -1" H2O
  East manifold pressure = ~"31 H2O
  West manifold = ~34" H2O
- 1830 – Continue feeding both trains @ 5 lbs/MMacf. Leave site.

Friday March 2, 2007

- 0715 CS & BH arrive on site. Silo still feeding 50 lbs/hr on each feeder, no alarms, no lakes of carbon on the ground!
- Everything is operating great at the moment %removal appears to be around 90%
- 11:39 - Changed injection rate to 3#/MMacf
- 1500 – Collect ash sample from hoppers 3-1 & 3-4. Ash hoppers 3-1, 3-2, 3-4, 4-1, 4-2, & 4-4 have all been isolated for several hours, 3-4, 4-1, & 4-4 had no ash.
- 1730 – Have installed a vibrator on 3C with a timer. Leaving now.

Saturday March 3, 2007

- 0830 – BH & CS on site after picking up some supplies from town.
- Hg removal still between 85 and 90 % (89.4% 18 hours) overnight at 3 lbs/MMacf.
- Ran STM at ESP inlet and outlet (one hour at inlet, two at outlet). Neither STM box created a data file! Recorded DGM m3 at start and stop of test.
- 1400 – Collect coal sample from north conveyor.
- 1500 – Collect ash sample from hoppers 3-1 & 3-4. Ash hoppers 3-1, 3-2, 3-4, 4-1, 4-2, & 4-4 have all been isolated for several hours, 3-4, 4-1, & 4-4 had no ash.
- 16:40 - Discharge Pressure up to 8.5 at 889 MW lowered down to 7.0
- 1700 – Leave site

Sunday March 4, 2007

- 0800 – Here again. Continue feeding at 3 lbs/MMacf. Plant switched to ColoWyo coal sometime during the night, mercury levels very low. Plant indicated that they would run out at 14:00
- Changed out Sncl2 impingers, rinsed crystals out of NaOH impingers.
- Cannot get either STM box to create data files on the compact flash cards.
- Precip operator is evacuating all ash hoppers this morning, then he will isolate them again, we will attempt to collect ash samples this afternoon.
- Blew out all injection ports (with the exception of a select few). No significant build up could be noticed except maybe the last 1 to 2 feet of the lance had some solids built up.
- No ash sample was obtained.
- 1530 leave site.

Monday March 5, 2007

- 0715 BH & CS on site. Carbon is still feeding at 3 lbs/MMacf (30 lbs/hour per side), silo level @ 0% full, load cells indicate 6100 lbs left in silo.
- 1000 – Start STM at inlet and outlet.
- 17:25 Decreased injection rate to 1.5 lb/MMacf
- 1830 leave site.

Tuesday March 6, 2007

- 0730 – BH & CS on site.
- Train # 2 tripped off at ~ 0407 hrs due to a feeder malfunction alarm. Cannot determine what caused this at this point. Reset alarm and started feeder.

Current Blower/Skid conditions:

- Power setting – 79.9%
- Hertz – 32
- Amps – 40
- Blower discharge pressure – 8 psi
- Train 1 suction - -1.4" H2O
- Train 1 pressure – 7 psi
- Train 1 feed rate – 15 lbs/hr
- Train 2 suction - -1.5: H2O
- Train 2 pressure – 8 psi
- Train 2 feed rate – 15 lbs/hr
- Additionally, there were two separate hopper fill malfunction alarms on train 2 overnight, probably due to the low silo level.
- 1010 – Another Feeder malfunction alarm has stopped the train 2 feeder. Reset
- 10:30 – Unit at low load(~650) feeder # 2 having constant problems
- 10:40 - due to skid problems increased injection rate back to 3.0
- 15:09 - Decreased the injection rate to 2 #/MMacf
- 16:44 – turned off carbon to check velocities at 610 mw
- 1815 - Turned on carbon @ 2 lbs/MMacf
- 1845 – Leave site.

Wednesday March 7, 2007

- 0715 – BH & CS on site
- 7:32 – Turned off feeders to take another crack at the velocities
- 8:39 – restarted feeders at 2 #/MMacf
- Ambient temperature around 75F notice % removal slipping despite constant feed and full load
- 1730 – Leave site.

Thursday March 8, 2007

- 07:00 – Turned off carbon feeders
- closed knife valves on silo
- Kept blower running
- Going to post the data, will update further once back in Denver if needed

APPENDIX D:

Source Testing

APPENDIX D1: Source Testing—August 15–18, 2005

METCO ENVIRONMENTAL
P.O. Box 598
Addison, TX 75001
(972) 931-7127

SOURCE EMISSIONS SURVEY
OF
ARKANSAS POWER & LIGHT COMPANY
INDEPENDENCE STEAM
ELECTRIC STATION
UNIT NUMBER 2 ESP INLET
AND OUTLET DUCTS
NEWARK, ARKANSAS
FOR
ADA-ES

AUGUST 2005

FILE NUMBER 05-233REV

" I certify that I have personally checked and am familiar with the information submitted herein, and based on my inquiries of those individuals immediately responsible for obtaining the information, I believe the submitted information is true, accurate, and complete. "

James R. Monfries
Senior Quality Assurance Manager

METCO ENVIRONMENTAL

TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
SUMMARY OF RESULTS	2
DISCUSSION OF RESULTS	12
DESCRIPTION OF SAMPLING LOCATIONS	15
SAMPLING AND ANALYTICAL PROCEDURES	18
DESCRIPTION OF TESTS	23
APPENDICES	25
A. Location of Sampling Points	
B. Source Emissions Calculations	
C. Calibration Data	
D. Field Testing Data	
E. Analytical Data	
F. Chain of Custody	
G. Resumes of Test Personnel	

SOURCE EMISSIONS SURVEY
ARKANSAS POWER & LIGHT COMPANY
INDEPENDENCE STEAM ELECTRIC STATION
UNIT NUMBER 2 ESP INLET AND OUTLET DUCTS
NEWARK, ARKANSAS
FOR
ADA-ES
FILE NUMBER 05-233

INTRODUCTION

METCO Environmental, P.O. Box 598, Addison, Texas, conducted a source emissions survey of Arkansas Power & Light Company, Independence Steam Electric Station, located in Newark, Arkansas, for ADA-ES, on August 15, 16, 17, and 18, 2005. The purpose of these tests was to determine the concentrations of particulate matter, hydrogen chloride, hydrogen bromide, hydrogen fluoride, and mercury at the Unit Number 2 ESP Inlet and Outlet Ducts.

The sampling was performed by the following METCO personnel: Steve Bornsen - Project Supervisor, Jason Brown, Rodney Malone, Ben Goebel, Ben Weber, Dustin Simpson, Doug Ware, Jason Sellers, and Joshua Orr.

The sampling followed the procedures set forth in the Code of Federal Regulations, Title 40, Chapter I, Part 60, Appendix A, Methods 1, 2, 3B, 4, 17, and 26A; and the Ontario Hydro Method, Revised July 7, 1999 (ASTM D-6785-02).

SUMMARY OF RESULTS

Unit Number 2 ESP Inlet Duct

Run Number	Particulate Matter Emissions (gr/dscf*)	(lbs/hr)	(lbs/mmBtu)
1	1.7794	3,916.47	3.352
2	1.5092	3,259.65	2.918
3	1.8450	4,199.78	3.346
Average	1.7112	3,791.97	3.205

Run Number	Hydrogen Chloride Emissions (dry ppm)	(lbs/hr)	(lbs/mmBtu)	Hydrogen Fluoride Emissions (dry ppm	(lbs/hr)	(lbs/mmBtu)	Hydrogen Bromide Emissions (dry ppm)	(lbs/hr)	(lbs/mmBtu)
1	0.36	0.522	4.46E-04	0.94	0.754	6.45E-04	0.01	0.044	3.80E-05
2	0.34	0.494	4.42E-04	0.70	0.551	4.93E-04	N.D.	N.D.	N.D.
3	0.47	0.705	5.61E-04	0.86	0.715	5.69E-04	0.01	0.032	2.51E-05
Average	0.39	0.574	4.83E-04	0.83	0.673	5.69E-04	< 0.01	< 0.025	< 2.10E-05

Unit Number 2 ESP Outlet Duct

Run Number	Particulate Matter Emissions (gr/dscf*)	(lbs/hr)	(lbs/mmBtu)
1	0.0102	22.10	0.021
2	0.0123	23.45	0.025
3	0.0126	26.60	0.027
Average	0.0117	24.05	0.024

Run Number	Hydrogen Chloride Emissions (dry ppm)	(lbs/hr)	(lbs/mmBtu)	Hydrogen Fluoride Emissions (dry ppm	(lbs/hr)	(lbs/mmBtu)	Hydrogen Bromide Emissions (dry ppm)	(lbs/hr)	(lbs/mmBtu)
1	0.44	0.626	6.07E-04	1.85	1.459	1.42E-03	0.02	0.054	5.29E-05
2	0.38	0.480	5.08E-04	1.10	0.761	8.05E-04	N.D.	N.D.	N.D.
3	0.49	0.690	6.99E-04	1.63	1.251	1.27E-03	0.01	0.046	4.67E-05
Average	0.44	0.599	6.05E-04	1.53	1.157	1.17E-03	< 0.01	< 0.033	< 3.32E-05

* 29.92 "Hg, 68°F (760 mm Hg, 20°C)
N.D. – None detected.

SUMMARY OF RESULTS

Unit Number 2 ESP Inlet Duct

Run Number	Particle Bound Mercury Emissions ($\mu g/m^3$)	Particle Bound Mercury Emissions (lbs/trillion Btu)	Oxidized Mercury Emissions ($\mu g/m^3$)	Oxidized Mercury Emissions (lbs/trillion Btu)	Elemental Mercury Emissions ($\mu g/m^3$)	Elemental Mercury Emissions (lbs/trillion Btu)	Total Mercury Mercury Emissions ($\mu g/m^3$)	Total Mercury Mercury Emissions (lbs/trillion Btu)
1	0.328	0.270	7.950	6.546	5.016	4.130	13.294	10.946
2	0.365	0.308	2.315	1.957	5.652	4.777	8.332	7.042
3	0.359	0.284	1.964	1.557	5.010	3.971	7.333	5.812
Average	0.351	0.287	4.076	3.353	5.226	4.293	9.653	7.933

Unit Number 2 ESP Outlet Duct

Run Number	Particle Bound Mercury Emissions ($\mu g/m^3$)	Particle Bound Mercury Emissions (lbs/trillion Btu)	Oxidized Mercury Emissions ($\mu g/m^3$)	Oxidized Mercury Emissions (lbs/trillion Btu)	Elemental Mercury Emissions ($\mu g/m^3$)	Elemental Mercury Emissions (lbs/trillion Btu)	Total Mercury Mercury Emissions ($\mu g/m^3$)	Total Mercury Mercury Emissions (lbs/trillion Btu)
1	< 0.013	< 0.012	4.160	3.820	3.729	3.424	< 7.902	< 7.256
2	0.052	0.046	3.327	2.928	4.204	3.701	7.583	6.675
3	0.094	0.087	2.037	1.898	4.266	3.974	6.397	5.959
Average	< 0.053	< 0.048	3.175	2.882	4.066	3.700	< 7.294	< 6.630

SUMMARY OF RESULTS

Unit Number 2 ESP Inlet Duct

EPA Method 17 Particulate Matter

Run Number	1	2	3
Date	08/17/05	08/17/05	08/18/05
Time	1103-1616	1803-2052	1100-1348
Duct Flow Rate - ACFM	455,232	443,763	465,525
Duct Flow Rate - DSCFM*	256,821	252,027	265,609
% Water Vapor - % Vol.	12.50	11.37	11.81
% CO_2 - % Vol.	14.8	14.6	14.0
% O_2 - % Vol.	5.4	5.8	4.8
% Excess Air @ Sampling Point	34.3	37.9	28.7
Stack Temperature - °F	329	331	323
Stack Pressure - "Hg	28.72	28.62	28.60
Percent Isokinetic	96.6	98.4	98.2
Volume Dry Gas Sampled - DSCF*	55.094	55.078	57.964
Particulate Matter Emissions <u>Nozzle & Thimble Catch</u> grains/dscf*	1.7794	1.5092	1.8450
grains/cf @ Stack Conditions	1.0003	0.8542	1.0490
lbs/hr	3,916.47	3,259.65	4,199.78
lbs/mmBtu	3.352	2.918	3.346

* 29.92 "Hg, 68°F (760 mm Hg, 20°C)

SUMMARY OF RESULTS

Unit Number 2 ESP Inlet Duct

EPA Method 26A

Run Number	1	2	3
Hydrogen Chloride - µg	846.1	815.4	1,162.8
Hydrogen Chloride Concentrations – dry ppm	0.36	0.34	0.47
Hydrogen Chloride Concentrations – lbs/hr	0.522	0.494	0.705
Hydrogen Chloride Concentrations – lbs/mmBtu	4.46E-04	4.42E-04	5.62E-04
Hydrogen Fluoride - µg	1,223.0	910.1	1,178.9
Hydrogen Fluoride Concentrations – dry ppm	0.94	0.70	0.86
Hydrogen Fluoride Concentrations – lbs/hr	0.754	0.551	0.715
Hydrogen Fluoride Concentrations – lbs/mmBtu	6.45E-04	4.93E-04	5.69E-04
Hydrogen Bromide - µg	72.0	N.D.	52.0
Hydrogen Bromide Concentrations – dry ppm	0.01	N.D.	0.01
Hydrogen Bromide Concentrations – lbs/hr	0.044	N.D.	0.032
Hydrogen Bromide Concentrations – lbs/mmBtu	3.80E-05	N.D.	2.51E-05

N.D. – None detected.

Note: Chorine and Bromine were not detected in the samples.

SUMMARY OF RESULTS

Unit Number 2 ESP Inlet Duct

Ontario Hydro Mercury

Run Number	1	2	3
Date	08/17/05	08/17/05	08/18/05
Time	1110-1527	1816-2105	1110-1350
Duct Flow Rate - ACFM	448,864	445,585	437,601
Duct Flow Rate - DSCFM*	256,671	253,438	248,598
% Water Vapor - % Vol.	12.36	12.38	12.64
% CO_2 - % Vol.	14.8	14.6	14.0
% O_2 - % Vol.	5.4	5.8	4.8
% Excess Air @ Sampling Point	34.3	37.9	28.7
Stack Temperature - °F	320	321	319
Stack Pressure - "Hg	28.73	28.62	28.60
Percent Isokinetic	95.1	103.2	101.6
Volume Dry Gas Sampled - DSCF*	55.967	58.109	56.112

* 29.92 "Hg, 68°F (760 mm Hg, 20°C)

SUMMARY OF RESULTS

Unit Number 2 ESP Inlet Duct

Ontario Hydro Mercury

Run Number	1	2	3
Particle Bound Mercury - µg	0.52	0.60	0.57
Particle Bound Mercury Emissions - µg/m^{3*}	0.328	0.365	0.359
Particle Bound Mercury Emissions - lbs/trillion Btu	0.270	0.308	0.284
Oxidized Mercury - µg	12.60	3.81	3.12
Oxidized Mercury Emissions - µg/m^{3*}	7.950	2.315	1.964
Oxidized Mercury Emissions - lbs/trillion Btu	6.546	1.957	1.557
Elemental Mercury - µg	7.95	9.30	7.96
Elemental Mercury Emissions - µg/m^{3*}	5.016	5.652	5.010
Elemental Mercury Emissions - lbs/trillion Btu	4.130	4.777	3.971
Total Mercury Emissions - µg/m^{3*}	13.294	8.332	7.333
Total Mercury Emissions - lbs/trillion Btu	10.946	7.042	5.812

* 29.92 "Hg, 68°F (760 mm Hg, 20°C)

SUMMARY OF RESULTS

Unit Number 2 ESP Outlet Duct

EPA Method 17 Particulate Matter

Run Number	1	2	3
Date	08/17/05	08/17/05	08/18/05
Time	1101-1514	1802-2048	1100-1350
Duct Flow Rate - ACFM	427,845	387,599	425,892
Duct Flow Rate - DSCFM*	252,709	222,254	245,498
% Water Vapor - % Vol.	11.85	11.23	12.15
% CO_2 - % Vol.	12.8	13.6	13.2
% O_2 - % Vol.	7.0	6.4	7.2
% Excess Air @ Sampling Point	49.1	43.2	51.8
Stack Temperature - °F	298	324	312
Stack Pressure - "Hg	28.68	28.59	28.60
Percent Isokinetic	97.4	97.4	95.3
Volume Dry Gas Sampled - DSCF*	71.536	62.928	67.971
Particulate Matter Emissions Nozzle & Thimble Catch grains/dscf*	0.0102	0.0123	0.0126
grains/cf @ Stack Conditions	0.0060	0.0070	0.0073
lbs/hr	22.10	23.45	26.60
lbs/mmBtu	0.021	0.025	0.027

* 29.92 "Hg, 68°F (760 mm Hg, 20°C)

SUMMARY OF RESULTS
Unit Number 2 ESP Outlet Duct
EPA Method 26A

Run Number	1	2	3
Hydrogen Chloride - µg	1,339.4	1,027.6	1,444.2
Hydrogen Chloride Emissions – dry ppm	0.44	0.38	0.49
Hydrogen Chloride Emissions – lbs/hr	0.626	0.480	0.690
Hydrogen Chloride Emissions – lbs/mmBtu	6.07E-04	5.08E-04	6.99E-04
Hydrogen Fluoride - µg	3,122.5	1,629.6	2,617.3
Hydrogen Fluoride Emissions – dry ppm	1.85	1.10	1.63
Hydrogen Fluoride Emissions – lbs/hr	1.459	0.761	1.251
Hydrogen Fluoride Emissions – lbs/mmBtu	1.42E-03	8.05E-04	1.27E-03
Hydrogen Bromide - µg	116.6	N.D.	96.4
Hydrogen Bromide Emissions – dry ppm	0.02	N.D.	0.01
Hydrogen Bromide Emissions – lbs/hr	0.054	N.D.	0.046
Hydrogen Bromide Emissions – lbs/mmBtu	5.29E-05	N.D.	4.67E-05

N.D. – None detected.

Note: Chorine and Bromine were not detected in the samples.

METCO ENVIRONMENTAL

SUMMARY OF RESULTS
Unit Number 2 ESP Outlet Duct
Ontario Hydro Mercury

Run Number	1	2	3
Date	0817/05	08/17/05	08/18/05
Time	1110-1443	1812-2108	1120-1403
Duct Flow Rate - ACFM	431,045	445,572	437,962
Duct Flow Rate - DSCFM*	246,156	242,361	243,978
% Water Vapor - % Vol.	11.74	13.75	13.13
% CO_2 - % Vol.	12.8	13.6	13.2
% O_2 - % Vol.	7.0	6.4	7.2
% Excess Air @ Sampling Point	49.1	43.2	51.8
Stack Temperature - °F	325	343	330
Stack Pressure - "Hg	28.68	28.59	28.60
Percent Isokinetic	99.2	96.0	95.8
Volume Dry Gas Sampled - DSCF*	53.223	67.614	67.961

* 29.92 "Hg, 68°F (760 mm Hg, 20°C)

SUMMARY OF RESULTS

Unit Number 2 ESP Outlet Duct

Ontario Hydro Mercury

Run Number	1	2	3
Particle Bound Mercury - µg	< 0.02	0.10	0.18
Particle Bound Mercury Emissions - µg/m^{3*}	< 0.013	0.052	0.094
Particle Bound Mercury Emissions - lbs/trillion Btu	< 0.012	0.046	0.087
Oxidized Mercury - µg	6.27	6.37	3.92
Oxidized Mercury Emissions - µg/m^{3*}	4.160	3.327	2.037
Oxidized Mercury Emissions - lbs/trillion Btu	3.820	2.928	1.898
Elemental Mercury - µg	5.62	8.05	8.21
Elemental Mercury Emissions - µg/m^{3*}	3.729	4.204	4.266
Elemental Mercury Emissions - lbs/trillion Btu	3.424	3.701	3.974
Total Mercury Emissions - µg/m^{3*}	< 7.902	7.583	6.397
Total Mercury Emissions - lbs/trillion Btu	< 7.256	6.675	5.959

* 29.92 "Hg, 68°F (760 mm Hg, 20°C)

DISCUSSION OF RESULTS

Unit Number 2 ESP Inlet Duct

The three tests for particulate matter, hydrogen chloride, hydrogen bromide, and hydrogen fluoride appeared to be valid representations of the actual emissions during the tests. All leak checks performed on the sampling train and the pitot tubes showed no leaks before or after each test. The indicative parameters calculated from the field data were in close agreement. The moisture percentages for the three tests were within 5.1 percent of the mean value. The measured flow rates (Q_s) for the tests were within 2.9 percent of the mean value. The rates of sampling for the three tests were within the specified limits (90 to 110 percent isokinetic). The greatest deviation from 100 percent isokinetic was 3.4 percent.

The calculated emissions (pounds per million Btu) of particulate matter for the three tests showed a range of -9.0 percent to +4.6 percent variation from the mean value.

The calculated emissions (pounds per million Btu) of hydrogen chloride for the three tests showed a range of -8.6 percent to +16.3 percent variation from the mean value.

The calculated emissions (pounds per million Btu) of hydrogen fluoride for the three tests showed a range of -13.4 percent to +13.4 percent variation from the mean value.

The concentrations of hydrogen bromide for one of the three tests were below the minimum detectable limit of the method.

The three tests for speciated mercury appeared to be valid representations of the actual emissions during the tests. All leak checks performed on the sampling train and the pitot tubes showed no leaks before or after each test. The indicative parameters calculated from the field data were in close agreement. The moisture percentages for the three tests were within 1.4 percent of the mean value. The measured flow rates (Q_s) for the tests were within 1.7 percent of the mean value. The rates of sampling for the three tests were within the specified limits (90 to 110 percent isokinetic). The greatest deviation from 100 percent isokinetic was 4.9 percent.

The calculated emissions (pounds per trillion Btu) of total mercury for the three tests showed a range of -26.7 percent to +38.0 percent variation from the mean value.

Unit Number 2 ESP Outlet Duct

The three tests for particulate matter, hydrogen chloride, hydrogen bromide, and hydrogen fluoride appeared to be valid representations of the actual emissions during the tests. All leak checks performed on the sampling train and the pitot tubes showed no leaks before or after each test. The indicative parameters calculated from the field data were in close agreement. The moisture percentages for the three tests were within 4.4 percent of the mean value. The measured flow rates (Q_s) for the tests were within 7.5 percent of the mean value. The rates of sampling for the three tests were within the specified limits (90 to 110 percent isokinetic). The greatest deviation from 100 percent isokinetic was 4.7 percent.

The calculated emissions (pounds per million Btu) of particulate matter for the three tests showed a range of -13.7 percent to +11.0 percent variation from the mean value.

The calculated emissions (pounds per million Btu) of hydrogen chloride for the three tests showed a range of -16.0 percent to +15.6 percent variation from the mean value.

The calculated emissions (pounds per million Btu) of hydrogen fluoride for the three tests showed a range of -30.9 percent to +21.9 percent variation from the mean value.

The concentrations of hydrogen bromide for one of the three tests were below the minimum detectable limit of the method.

The three tests for speciated mercury appeared to be valid representations of the actual emissions during the tests. All leak checks performed on the sampling train and the pitot tubes showed no leaks before or after each test. The indicative parameters calculated from the field data were in close agreement. The moisture percentages for the three tests were within 8.8 percent of the mean value. The measured flow rates (Q_s) for the tests were within 0.8 percent of the mean value. The rates of sampling for the three tests were within the specified limits (90 to 110 percent isokinetic). The greatest deviation from 100 percent isokinetic was 4.2 percent.

The calculated emissions (pounds per trillion Btu) of total mercury for the three tests showed a range of -10.1 percent to +9.4 percent variation from the mean value.

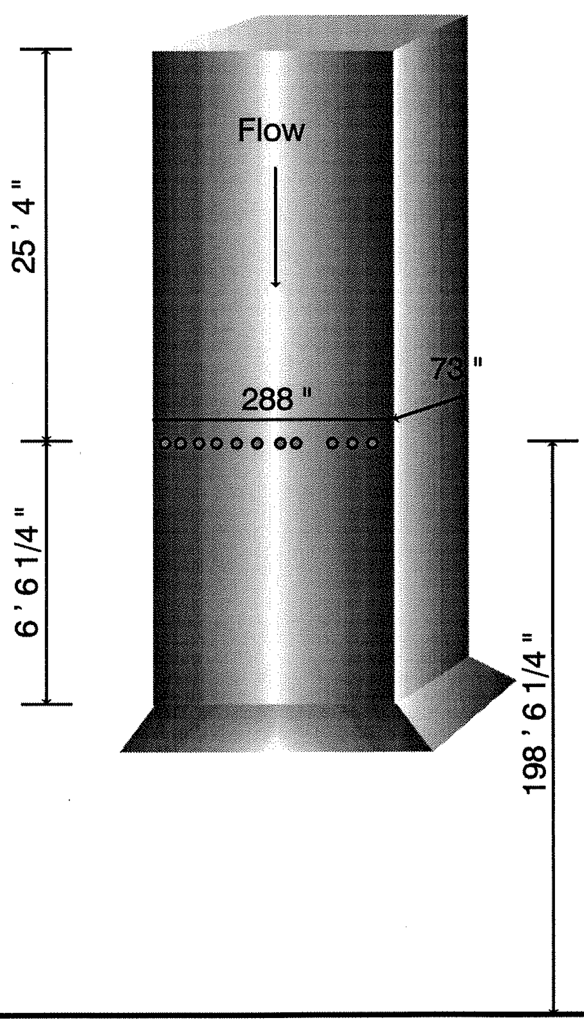
DESCRIPTION OF SAMPLING LOCATIONS

The sampling location on the Unit Number 2 ESP Inlet Duct is 198 feet 6 1/4 inches above the ground. The sampling ports are located 25 feet 4 inches (2.61 equivalent duct diameters) downstream from a bend in the duct and 6 feet 6 1/4 inches (0.67 equivalent duct diameters) upstream from an expansion in the duct.

The sampling location on the Unit Number 2 ESP Outlet Duct is approximately 200 feet above the ground. The sampling ports are located 6 feet 11 inches (0.71 equivalent duct diameters) downstream from a constriction in the duct and 3 feet 2 inches (0.33 equivalent duct diameters) upstream from a bend in the duct.

SAMPLING LOCATION

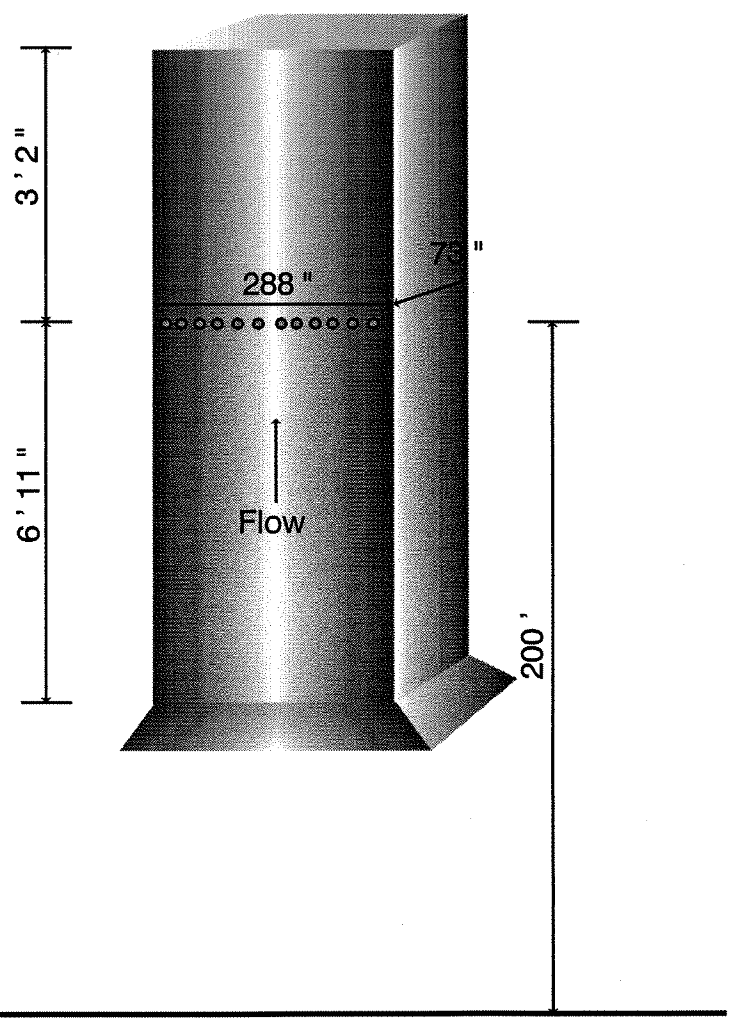
Unit Number 2 ESP Inlet Duct



Not to Scale

SAMPLING LOCATION

Unit Number 2 ESP Outlet Duct



Not to Scale

SAMPLING AND ANALYTICAL PROCEDURES

The sampling followed the procedures set forth in the Code of Federal Regulations, Title 40, Chapter I, Part 60, Appendix A, Methods 1, 2, 3B, 4, 17, and 26A; and the Ontario Hydro Method, Revised July 7, 1999 (ASTM D-6785-02).

A preliminary velocity traverse was made at eight of the eleven ports on the Unit Number 2 ESP Inlet Duct, in order to determine the uniformity and magnitude of the flow prior to testing. All traverse points were checked for cyclonic flow and the average angle of flow was equal to 4.8 degrees. Alternate procedures would be required if the angle of flow was greater than 20 degrees. Four traverse points were sampled from each of the eight ports for a total of thirty-two traverse points.

A preliminary velocity traverse was made at six of the twelve ports on the Unit Number 2 ESP Outlet Duct, in order to determine the uniformity and magnitude of the flow prior to testing. All traverse points were checked for cyclonic flow and the average angle of flow was equal to 5.2 degrees. Alternate procedures would be required if the angle of flow was greater than 20 degrees. Four traverse points were sampled from each of the eight ports for a total of thirty-two traverse points.

The sampling trains were leak-checked at the nozzle at 15 inches of mercury vacuum before each test, and again after each test at the highest vacuum reading recorded during the test. This was done to predetermine the possibility of a diluted sample.

The pitot tube lines were checked for leaks before and after each test under both a vacuum and a pressure. The lines were also checked for clearance and the manometer was zeroed before each test.

An integrated orsat sample was collected and analyzed according to EPA Method 3B during each test.

Particulate Matter/Halogens

Triplicate samples for particulate matter, hydrogen chloride, hydrogen bromide, and hydrogen fluoride were collected from each source. The samples were taken according to EPA Methods 1, 2, 3B, 4, 17, and 26A. For each run, samples of four-minute duration were taken isokinetically at each of the thirty-two traverse points for a total sampling time of 128 minutes. Reagent blanks were submitted.

The " front-half " of the sampling train contained the following components:

Quartz Nozzle
In-Stack Quartz Fiber Thimble and Filter in a Glass Assembly
Heated Glass Probe @ 248°F ± 25°F

The " back-half " of the sampling train contained the following components:

Impinger Number	Contents	Amount	Parameter Collected
1	0.1N Sulfuric Acid	100 ml	Halogens
2	0.1N Sulfuric Acid	100 ml	Halogens
3	Empty	----	Halogens and Moisture
4	0.1N Sodium Hydroxide	100 ml	Halogens
5	0.1N Sodium Hydroxide	100 ml	Halogens
6	Silica Gel	200 g	Moisture

Particulate matter emissions were calculated from gravimetric analysis of the "front-half" collections.

The halogen samples were analyzed by ion chromatography.

Speciated Mercury

Triplicate samples for speciated mercury were collected from each source. The samples were taken according to EPA Methods 1, 2, 3B, 4, 5, and 17; and the Ontario Hydro Method, Revised July 7, 1999. For Run Number 1 on the Inlet Duct, samples of four-minute duration were taken isokinetically at twenty-eight traverse points for a total sampling time of 96 minutes. For all other runs, samples of four-minute duration were taken isokinetically at each of the thirty-two traverse points for a total sampling time of 128 minutes. Blank train samples and reagent blanks were submitted.

The " front-half " of the sampling train contained the following components:

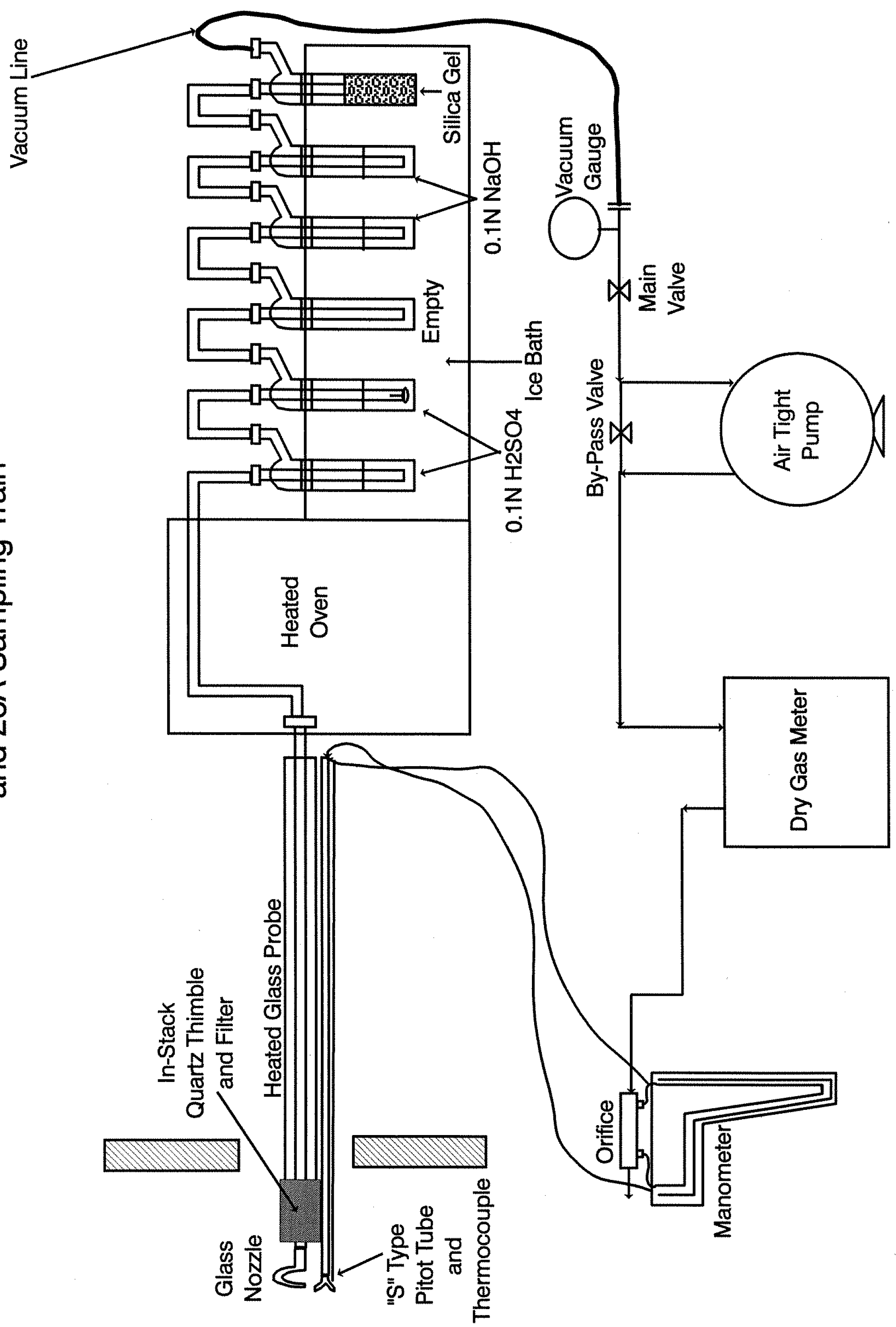
Quartz Nozzle
In-Stack Quartz Fiber Thimble and Filter in a Glass Assembly
Heated Glass Probe @ 248°F ± 25°F

The " back-half " of the sampling train contained the following components:

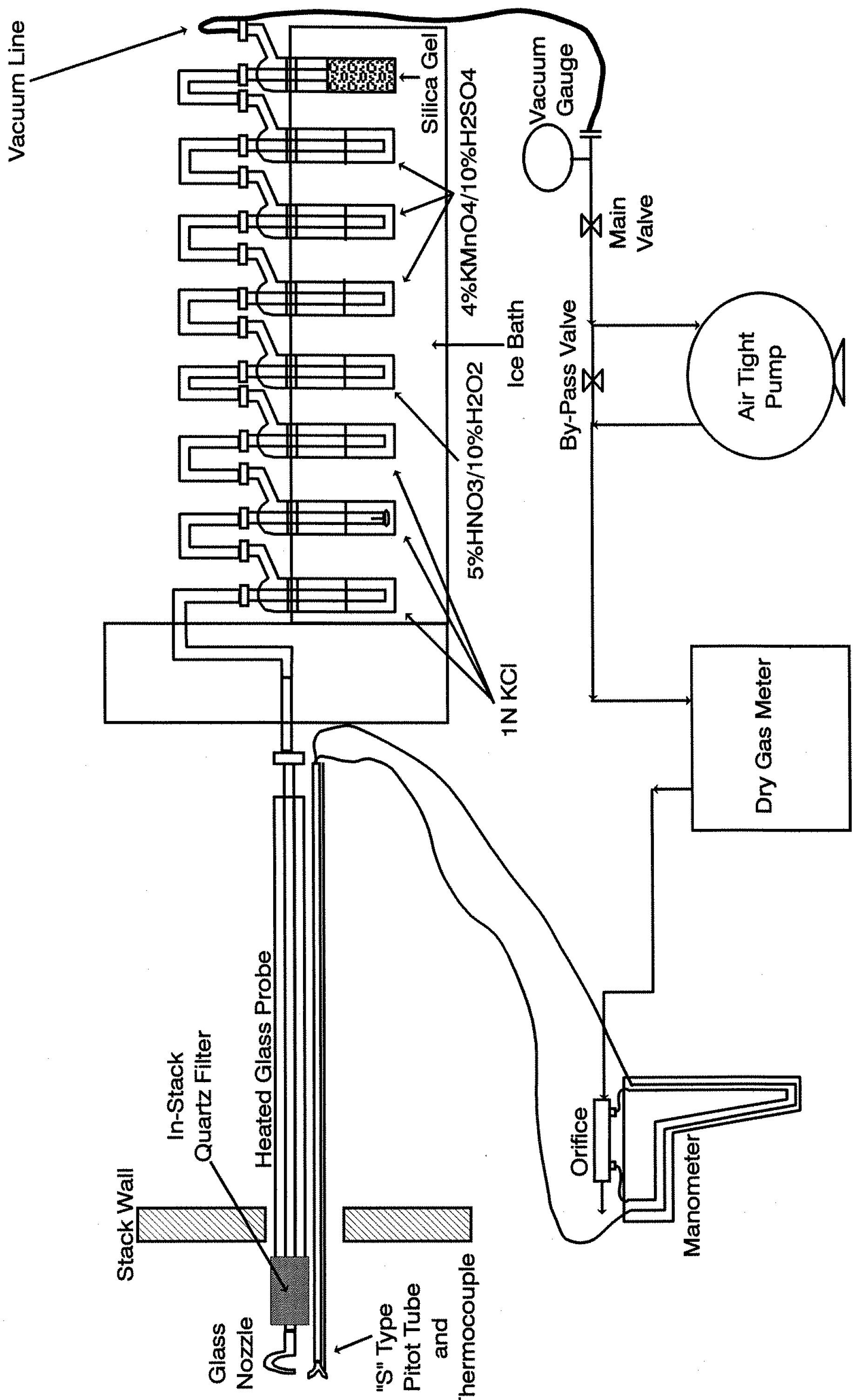
Impinger Number	Contents	Amount	Parameter Collected
1	1 mol/L KCl	100 ml	Oxidized Mercury
2	1 mol/L KCl	100 ml	Oxidized Mercury
3	1 mol/L KCl	100 ml	Oxidized Mercury
4	5% HNO_3 and 10% H_2O_2	100 ml	Elemental Mercury
5	4% $KMnO_4$ and 10% H_2SO_4	100 ml	Elemental Mercury
6	4% $KMnO_4$ and 10% H_2SO_4	100 ml	Elemental Mercury
7	4% $KMnO_4$ and 10% H_2SO_4	100 ml	Elemental Mercury
8	Silica Gel	200 g	Moisture

The mercury samples were analyzed by cold vapor atomic absorption spectroscopy.

Schematic Diagram of the EPA Combined Methods 17 and 26A Sampling Train



Schematic Diagram of the Ontario Hydro Method Sampling Train



DESCRIPTION OF TESTS

Personnel from METCO Environmental arrived at the plant at 3:00 p.m. on Monday, August 15, 2005. After meeting with plant personnel and attending a brief safety orientation, the equipment was moved onto the Unit Number 2 ESP Inlet and Outlet Ducts. The equipment was secured for the night and all work was completed at 7:00 p.m.

On Tuesday, August 16, work began at 7:45 a.m. The equipment was prepared for testing. The preliminary data was collected. Testing was delayed until the scaffolding was completed. The equipment was secured for the night and all work was completed at 7:15 p.m.

On Wednesday, August 17, work began at 9:00 a.m. The equipment was prepared for testing. The first set of tests for particulate matter, hydrogen chloride, hydrogen fluoride, and hydrogen bromide began at 11:01 a.m. Testing continued until completion of the second set of tests at 8:52 p.m. The first set of tests for speciated mercury began at 11:10 a.m. Testing continued until completion of the second set of tests at 9:08 p.m. The samples were recovered. The equipment was secured for the night and all work was completed at 11:00 p.m.

On Thursday, August 18, work began at 9:15 a.m. The equipment was prepared for testing. The third set of tests for particulate matter, hydrogen chloride, hydrogen fluoride, and hydrogen bromide began at 11:00 a.m. and was completed at 1:50 p.m. The third set of tests for speciated mercury began at 11:10 a.m. and was completed at 2:03 p.m.

The equipment was moved off of the sampling locations and loaded into the sampling van. The samples were recovered and transported to METCO Environmental's laboratory in Dallas, Texas, for analysis and evaluation.

Operations at Arkansas Power & Light Company, Independence Steam Electric Station, Unit Number 2 ESP Inlet and Outlet Ducts, located in Newark, Arkansas, for ADA-ES, were completed at 5:00 pm. on Thursday, August 18, 2005.

APPENDICES

A. Location of Sampling Points

B. Source Emissions Calculations

C. Calibration Data

D. Field Testing Data

E. Analytical Data

F. Chain of Custody

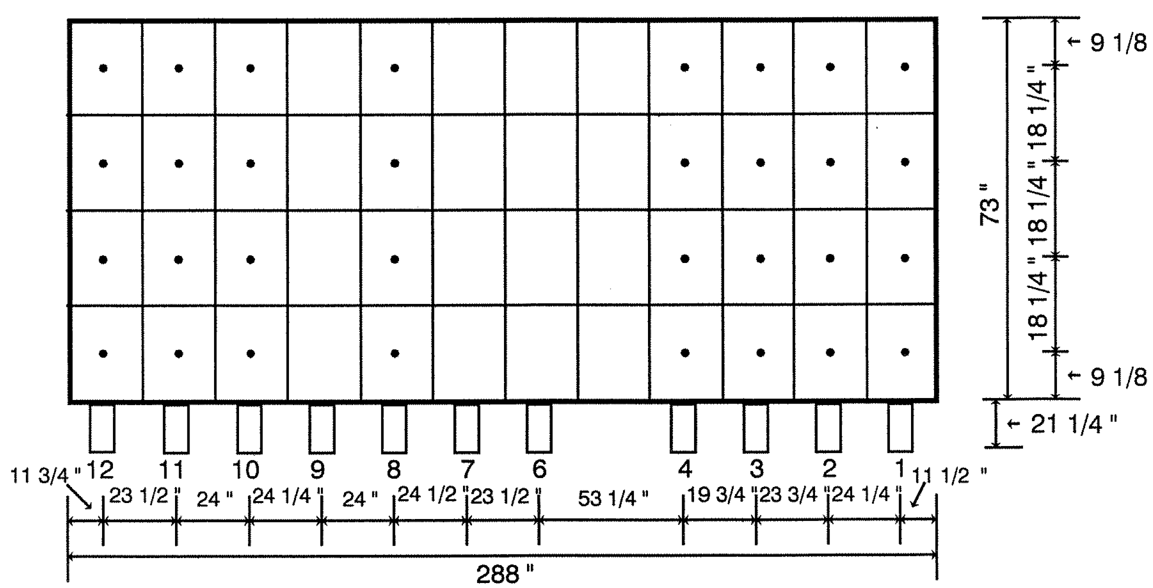
G. Resumes of Test Personnel

METCO ENVIRONMENTAL

APPENDIX A

Location of Sampling Points
Unit Number 2 ESP Inlet Duct

The sampling ports are located 25 feet 4 inches (2.61 equivalent duct diameters) downstream from a bend in the duct and 6 feet 6 1/4 inches (0.67 equivalent duct diameters) upstream from an expansion in the duct. The locations of the sampling points were calculated as follows:



Note: The duct has 17 " of insulation. Port 5 does not exist. Ports 6 and 7 are not part of the gas stream and were not included in the calculation of the area. The width of where Ports 6 and 7 are located is 5 ' 5 ". This leaves a width of 18 ' 7 " on which the area was calculated. A plant monitor probe is located in Port 9.

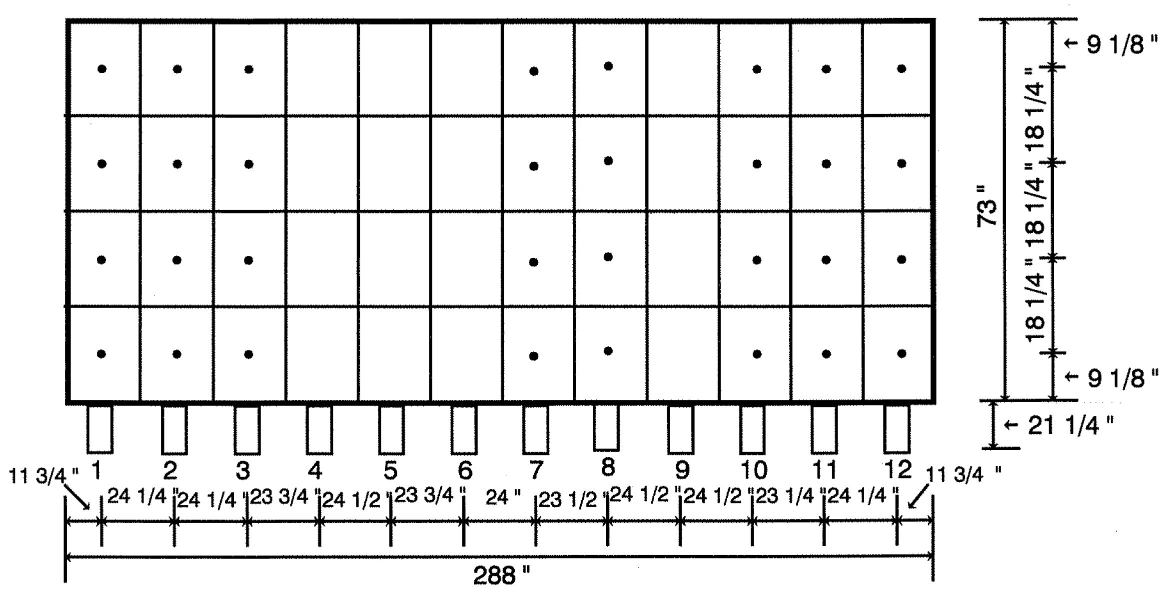
Not to Scale

APPENDIX A

Location of Sampling Points

Unit Number 2 ESP Outlet Duct

The sampling ports are located 6 feet 11 inches (0.71 equivalent duct diameters) downstream from a constriction in the duct and 3 feet 2 inches (0.33 equivalent duct diameters) upstream from a bend in the duct. The locations of the sampling points were calculated as follows:



Note: The duct has 17 " of insulation. Port 4 was not used. Ports 5 and 6 were not accessible and could not be sampled. A plant monitor probe is located in Port 9.

Not to Scale

APPENDIX B

Nomenclature and Equations
for
Calculation of Source Emissions

NOMENCLATURE FOR PARTICULATE CALCULATIONS

Symbol	English Units	Metric Units	Description
A_s	in.^{2}	m^2	Stack Area
C_{an}	gr/dscf*	g/dscm*	Particulate - probe, cyclone, and filter
C_{ao}	gr/dscf*	g/dscm*	Particulate - total
C_{at}	gr/CF @ stack conditions	g/m^3	Particulate - probe, cyclone, and filter
C_{au}	gr/CF @ stack conditions	g/m^3	Particulate - total
C_{aw}	lbs/hr	kg/hr	Particulate - probe, cyclone, and filter
C_{ax}	lbs/hr	kg/hr	Particulate - total
C_p			Pitot Tube Calibration Factor
D_n	in.	m	Sampling Nozzle Diameter
%EA			Percent Excess Air at sampling point
g	32.174 ft/sec^2		Acceleration of Gravity
%I			Percent Isokinetic
%M			Percent Moisture in the stack gas by volume
M_d			Mole fraction of dry gas

* 29.92 " Hg, 68° F (760 mm Hg, 20° C)

Symbol	English Units	Metric Units	Description
m_f	mg	mg	Particulate - probe, cyclone, and filter
M_{water}	18 lb/lb-mole		Molecular Weight of water
m_t	mg	mg	Particulate - total
MW	lb/lb-mole	g/g-mole	Molecular Weight of stack gas
MW_{air}	28.96 lb/ lb-mole		Molecular Weight of air
MW_d	lb/lb-mole	g/g-mole	Molecular Weight of dry stack gas
P_b	"Hg Absolute	mm Hg	Barometric Pressure
P_m	"H_2O	mm H_2O	Orifice Pressure drop
P_s	"Hg Absolute	mm Hg	Stack Pressure
ΔP	"H_2O	mm H_2O	Velocity Head of stack gas
P_{std}	29.92 "Hg	760 mm Hg	Standard Barometric Pressure
Q_a	ACFM	m^3/hr	Stack Gas Volume at actual stack conditions
Q_s	DSCFM*	dscm/hr*	Stack Gas Volume at 29.92 "Hg, 528°R, dry
R	21.83 "Hg-ft^3/lb-mole°R		Universal Gas Constant
T_m	°F	°C	Average Gas Meter Temperature

* 29.92 " Hg, 68° F (760 mm Hg, 20° C)

Symbol	English Units	Metric Units	Description
T_t	min	min	Net time of test
T_s	°F	°C	Stack Temperature
T_{std}	528°R	293°K	Standard Temperature
V_m	ft^3	m^3	Volume of dry gas sampled @ meter conditions
Vm_{std}	dscf*	dscm*	Volume of dry gas sampled @ standard conditions
V_s	fpm	m/sec	Stack velocity @ stack conditions
V_w	ml	ml	Total water collected in impingers and silica gel
Vw_{gas}	scf*	scm*	Volume of water vapor collected @ standard conditions
ρ_{air}	0.0752 lbs/ft^3		Density of Air
ρ_{water}	1 g/ml		Density of Water
ρ_{man}	62.32 lbs/ft^3		Density of Manometer Oil

Standard Conditions: 29.92 "Hg, 68°F (760 mm Hg, 20°C)

* 29.92 " Hg, 68° F (760 mm Hg, 20° C)

EXAMPLE CALCULATIONS

1. Volume of dry gas sampled at standard conditions. *

$$Vm_{std} = Vm \left(\frac{T_{std}}{T_m + 460}\right) \left[\frac{P_b + \frac{P_m}{13.6}}{P_{std}}\right]$$

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = dscf$$

$$Vm_{std} = dscf \times 0.028317 = dscm$$

2. Volume of water vapor collected at standard conditions. *

$$Vw_{gas} = \frac{(V_w - gms\ SO_2 - gms\ H_2S)\ \rho_{water}\ R\ T_{std}}{P_{std}\ M_{water}\ 453.6}$$

$$Vw_{gas} = 0.0472\ (V_w - gms\ SO_2 - gms\ H_2S) = scf$$

$$Vw_{gas} = scf \times 0.028317 = scm$$

3. Percent moisture in stack gas.

$$\%M = \frac{Vw_{gas}}{Vm_{std} + Vw_{gas}} \times 100 = \%$$

* 29.92 " Hg, 68° F (760 mm Hg, 20° C)

4. Mole fraction of dry gas.

$$M_d = \frac{100 - \%M}{100}$$

5. Average molecular weight of dry stack gas.

$$MW_d = \left[\%CO_2 \ x \ \frac{44}{100}\right] + \left[\%O_2 \ x \ \frac{32}{100}\right] + \left[\%N_2 \ x \ \frac{28}{100}\right] + \left[\%CO \ x \ \frac{28}{100}\right] = lb/lb - mole$$

$$= g/g - mole$$

6. Molecular weight of stack gas.

$$MW = MW_d \ x \ M_d + 18\,(1 - M_d) = \frac{lb}{lb - mole} = g/g - mole$$

7 Percent excess air at sampling point.

$$\%EA = \frac{100\,[\%O_2 - (0.5\,\%CO)]}{0.265\,(\%N_2) - [\%O_2 - (0.5\,\%CO)]}$$

8. Stack Pressure.

$$P_s = P_b + \frac{Stack\ Pressure\ "\ H_2O}{13.6} = "\ Hg\ Absolute$$

$$P_s = "\ Hg\ Abs.\ x\ 25.4 = mm\ Hg$$

* 29.92 " Hg, 68° F (760 mm Hg, 20° C)

9. Stack velocity at stack conditions.

$$V_s = C_p\,60 \left[\frac{2g \times \rho_{man} \times P_{std} \times MW_{air} \times (T_s + 460) \times \Delta P}{12 \times \rho_{air} \times P_s \times MW \times T_{std}} \right]^{1/2}$$

$$V_s = 5{,}123.8\, C_p \left[\frac{(T_s + 460)}{P_s \times MW} \right]^{1/2} \sqrt{\Delta P} \text{ average} = \text{fpm}$$

$$V_s = \text{fpm} \times 0.00508 = \text{m/sec}$$

10. Dry stack gas volume at standard conditions. *

$$Q_s = \frac{1}{144} V_s \times A_s \times M_d \times \frac{T_{std}}{T_s + 460} \times \frac{P_s}{P_{std}}$$

$$Q_s = \frac{0.123\, V_s \times A_s \times M_d \times P_s}{T_s + 460} = DSCFM$$

$$Q_s = DSCFM \times 1.6990 = dscm/hr$$

11. Actual stack gas volume at stack conditions.

$$Q_a = \frac{V_s \times A_s}{144} = ACFM$$

$$Q_a = ACFM \times 1.6990 = m^3/hr$$

* 29.92 " Hg, 68° F (760 mm Hg, 20° C)

12. Percent Isokinetic.

$$\%I = \frac{Vm_{std} \ x\ (T_s + 460)\ x\ P_{std}\ x\ 100\ x\ 144\ in^2/ft^2}{M_d\ x\ T_{std}\ x\ P_s\ x\ T_t\ x\ V_s\ (\frac{\pi\ x\ D_n^2}{4})}$$

$$\%I = \frac{1039\ x\ Vm_{std}\ x\ (T_s + 460)}{M_d\ x\ P_s\ x\ T_t\ x\ V_s\ x\ D_n^2}$$

13. Particulate – probe, cyclone, and filter.

$$C_{an} = \frac{m_f}{Vm_{std}}\ x\ \frac{1\ gr}{64.8\ mg}$$

$$C_{an} = 0.0154\ x\ \frac{m_f}{Vm_{std}} = gr/dscf\ *$$

$$C_{an} = gr/dscf\ \ x\ 2.290 = g/dscm\ *$$

14. Particulate total.

$$C_{ao} = 0.0154\ x\ \frac{m_t}{Vm_{std}} = gr/dscf\ *$$

$$C_{ao} = gr/dscf\ \ x\ 2.290 = g/dscm\ *$$

* 29.92 " Hg, 68° F (760 mm Hg, 20° C)

15. Particulate – probe, cyclone, and filter at stack conditions.

$$C_{at} = C_{an} \, x \, \frac{P_s}{P_{std}} \, x \, \frac{(T_{std})}{(T_s + 460)} \, x \, M_d$$

$$C_{at} = \frac{17.65 \, x \, C_{an} \, x \, P_s \, x \, M_d}{T_s + 460} = gr/CF$$

$$C_{at} = gr/CF \; x \; 2.290 = gr/m^3$$

16. Particulate – total, at stack conditions.

$$C_{au} = \frac{17.65 \, x \, C_{ao} \, x \, P_s \, x \, M_d}{T_s + 460} = gr/CF$$

$$C_{au} = gr/CF \; x \; 2.290 = gr/m^3$$

17. Particulate – probe, cyclone, and filter.

$$C_{aw} = C_{an} \, x \, Q_s \, x \, \frac{60 \text{ min}}{1 \, hr} \, x \, \frac{1 \, lb}{7000 \, gr}$$

$$C_{aw} = 0.00857 \, x \, C_{an} \, x \, Q_s = lbs/hr$$

$$C_{aw} = lbs/hr \; x \; 0.4536 = kg/hr$$

* 29.92 " Hg, 68° F (760 mm Hg, 20° C)

18. Particulate – total.

$C_{ax} = 0.00857 \times C_{ao} \times Q_s = lbs/hr$

$C_{ax} = lbs/hr \times 0.4536 = kg/hr$

METCO ENVIRONMENTAL

EXAMPLE CALCULATIONS

$$\text{lbs/hr} = \frac{\text{mg}}{Vm_{std}} \times 2.205 \times 10^{-6}\ \text{lbs/mg} \times \text{DSCFM*} \times 60\ \text{min/hr}$$

Vm_{std} = Volume of dry gas sampled (dscf*)
DSCFM* = Stack Flow Rate

$$\text{ppm} = \frac{\text{mg}}{Vm_{std}\ (m^3)} \times \frac{24.04}{\text{MW}}$$

24.04 = Ideal Gas Constant liters/g-mole
Vm_{std} = Volume of dry gas sampled (m^3*)
MW = Molecular Weight

Compound	Molecular Weight
Hydrogen Fluoride	20.01
Hydrogen Chloride	36.45
Hydrogen Bromide	80.92

* 29.92 "Hg, 68°F (760 mm Hg, 20°C)

EXAMPLE CALCULATIONS

$$\text{lbs/trillion Btu} = \frac{\text{lbs/dscf* } \times \text{ } F_d \text{ factor } \times \text{ } 20.9\%O_2}{20.9\%O_2 - \%O_2 \text{ measured}}$$

F_d = Oxygen based F factor

Fuel	F_d factor
Bituminous Coal	9.780×10^9 dscf*/trillion Btu

* 29.92 "Hg, 68°F (760 mm Hg, 20°C)

EXAMPLE CALCULATIONS

$$\text{lbs/million Btu} = \frac{\text{gr/dscf} \times \dfrac{1\text{ lb}}{7{,}000\text{ gr}} \times F_d \text{ factor} \times 20.9\%O_2}{20.9\%O_2 - \%O_2 \text{ measured}}$$

$$\text{lbs/million Btu} = \frac{\text{lbs/dscf}^* \times F_d \text{ factor} \times 20.9\%O_2}{20.9\%O_2 - \%O_2 \text{ measured}}$$

F_d = Oxygen based F factor

Fuel	F_d Factor
Bituminous Coal	9,780 dscf*/million Btu

* 29.92 "Hg, 68°F (760 mm Hg, 20°C)

SOURCE EMISSION SURVEY

JOB NUMBER: 05-233
JOB NAME: ADA-ES
LOCATION: NEWARK, ARKANSAS
UNIT TESTED: UNIT NUMBER 2 ESP INLET DUCT - METHODS 17 & 26A

SOURCE EMISSION CALCULATIONS

SYMBOL	DESCRIPTION	UNITS	RUN NUMBER 1	RUN NUMBER 2	RUN NUMBER 3
DATE			08/17/05	08/17/05	08/18/05
BEGIN TIME			1103	1803	1100
END TIME			1616	2052	1348
P(b)	BAROMETRIC PRESSURE	"Hg Abs. (mm Hg)	29.76 (756.00)	29.66 (753.00)	29.67 (754.00)
P(m)	ORIFICE PRESSURE DROP	"H2O (mm H2O)	0.544 (13.800)	0.553 (14.000)	0.620 (15.700)
	DGM CALIBRATION FACTOR		0.997	0.997	0.997
V(m)	VOLUME DRY GAS SAMPLED @ METER CONDITIONS LEAK CHECK VOLUME	ft.^3 (m^3) ft.^3	57.402 (1.625) 3.328	58.628 (1.660) 3.387	61.779 (1.749) 5.895
T(m)	AVERAGE GAS METER TEMPERATURE	DEG.F (DEG.C)	88 (31)	98 (37)	99 (37)
V(m[std])*	VOLUME DRY GAS SAMPLED @ STANDARD CONDITIONS*	DSCF (DSCM)	55.094 (1.560)	55.078 (1.560)	57.964 (1.641)
V(w)	TOTAL WATER COLLECTED, IMPINGERS & SILICA GEL	ml	166.8	149.7	164.4
V(w[gas])	VOLUME WATER VAPOR COLLECTED @ STANDARD CONDITIONS*	SCF (SCM)	7.873 (0.223)	7.066 (0.200)	7.760 (0.220)
%M	MOISTURE IN STACK GAS BY VOLUME	%	12.50	11.37	11.81
Md	MOL FRACTION OF DRY GAS		0.8750	0.8863	0.8819
Tt	NET TIME OF TEST	MINUTES	128	128	128

* 68 Deg.F, 29.92 "Hg (20 Deg.C, 760 mm Hg)

METCO ENVIRONMENTAL

SOURCE EMISSION CALCULATIONS

JOB NUMBER: 05-233
JOB NAME: ADA-ES
LOCATION: NEWARK, ARKANSAS
UNIT TESTED: UNIT NUMBER 2 ESP INLET DUCT - METHODS 17 & 26A

			RUN NUMBER		
SYMBOL	DESCRIPTION	UNITS	1	2	3
CO2		%	14.8	14.6	14.0
O2		%	5.4	5.8	4.8
CO		%	0.0	0.0	0.0
N2		%	79.8	79.6	81.2
%EA	EXCESS AIR @ SAMPLING POINT	%	34.3	37.9	28.7
MWd	MOLECULAR WEIGHT OF DRY STACK GAS	LB/LB-MOLE (g/g-MOLE)	30.58 (30.58)	30.57 (30.57)	30.43 (30.43)
MW	MOLECULAR WEIGHT OF STACK GAS	LB/LB-MOLE (g/g-MOLE)	29.01 (29.01)	29.14 (29.14)	28.96 (28.96)
Cp	PITOT TUBE CALIBRATION		0.806	0.806	0.808
DELTA P	VELOCITY HEAD OF STACK GAS	"H2O (mm H20)	1.032 (26.200)	0.977 (24.800)	1.063 (27.000)
DELTA P ^(1/2)		"H2O	1.002	0.976	1.023
Ts	STACK TEMPERATURE	DEG. F (DEG. C)	329 (165)	331 (166)	323 (162)
Ps	STACK PRESSURE	"Hg Abs. (mm Hg) "H20	28.72 (729.00) -14.10	28.62 (727.00) -14.10	28.60 (726.00) -14.50
Vs	STACK VELOCITY @ STACK CONDITIONS	FPM (m/SEC.)	4,027 (20)	3,925 (20)	4,118 (21)
As	STACK AREA	(SQ.INCHES) (SQ.METERS)	16,279 (11)	16,279 (11)	16,279 (11)
Qs	DRY STACK GAS VOLUME @ STANDARD CONDITIONS* WET STACK GAS VOLUME @ STANDARD CONDITIONS*	DSCFM (DSCM/HR) WSCFH	256,821 (436,339) 17,610,583	252,027 (428,194) 17,061,514	265,609 (451,270) 18,070,688
Qa	ACTUAL STACK GAS VOLUME @ STACK CONDITIONS	ACFM (m^3/HR)	455,232 (773,439)	443,763 (753,953)	465,525 (790,927)
Dn	SAMPLING NOZZLE DIAM.	IN. (m)	0.190 (0.005)	0.190 (0.005)	0.190 (0.005)
%I	PERCENT ISOKINETIC	%	96.6	98.4	98.2

* 68 Deg.F, 29.92 "Hg (20 Deg.C, 760 mm Hg)

SOURCE EMISSION CALCULATIONS

JOB NUMBER: 05-233
JOB NAME: ADA-ES
LOCATION: NEWARK, ARKANSAS
UNIT TESTED: UNIT NUMBER 2 ESP INLET DUCT - METHODS 17 & 26A

SYMBOL	DESCRIPTION	UNITS	RUN NUMBER 1	RUN NUMBER 2	RUN NUMBER 3
Mf	PARTICULATE - PROBE, CYCLONE AND FILTER	mg	6,366.0	5,397.6	6,944.5
Mt	PARTICULATE - TOTAL	mg	----	----	----
Can	PARTICULATE - PROBE,	gr/DSCF*	1.7794	1.5092	1.8450
	CYCLONE AND FILTER	(g/DSCM)	(4.0749)	(3.4560)	(4.2251)
Cao	PARTICULATE - TOTAL	gr/DSCF*	----	----	----
		(g/DSCM)	----	----	----
Cat	PARTIC.-PROBE, CYCLONE	gr/CF	1.0003	0.8542	1.0490
	AND FILTER @ STACK COND.	(g/m3)	(2.2907)	(1.9561)	(2.4022)
Cau	PARTICULATE - TOTAL @	gr/CF	----	----	----
	STACK CONDITIONS	(g/m3)	----	----	----
Caw	PARTICULATE - PROBE,	LBS/HR	3,916.47	3,259.65	4,199.78
	CYCLONE AND FILTER	(Kg/HR)	(1,776.51)	(1,478.58)	(1,905.02)
Cax	PARTICULATE - TOTAL	LBS/HR	----	----	----
		(Kg/HR)	----	----	----

* 68 Deg.F, 29.92 "Hg (20 Deg.C, 760 mm Hg)

METCO ENVIRONMENTAL

SOURCE EMISSION SURVEY

JOB NUMBER: 05-233
JOB NAME: ADA-ES
LOCATION: NEWARK, ARKANSAS
UNIT TESTED: UNIT NUMBER 2 ESP INLET DUCT - ONTARIO HYDRO

SOURCE EMISSION CALCULATIONS

SYMBOL	DESCRIPTION	UNITS	RUN NUMBER 1	2	3
DATE			08/17/05	08/17/05	08/18/05
BEGIN TIME			1110	1816	1110
END TIME			1527	2105	1350
P(b)	BAROMETRIC PRESSURE	"Hg Abs. (mm Hg)	29.77 (756.00)	29.66 (753.00)	29.67 (754.00)
P(m)	ORIFICE PRESSURE DROP	"H2O (mm H2O)	0.642 (16.300)	0.785 (19.900)	0.724 (18.400)
	DGM CALIBRATION FACTOR		1.008	1.008	1.008
V(m)	VOLUME DRY GAS SAMPLED @ METER CONDITIONS LEAK CHECK VOLUME	ft.^3 (m^3) ft.^3	57.746 (1.635) 1.422	61.043 (1.729) 3.036	59.148 (1.675) 2.005
T(m)	AVERAGE GAS METER TEMPERATURE	DEG.F (DEG.C)	83 (28)	91 (33)	93 (34)
V(m[std])*	VOLUME DRY GAS SAMPLED @ STANDARD CONDITIONS*	DSCF (DSCM)	55.967 (1.585)	58.109 (1.645)	56.112 (1.589)
V(w)	TOTAL WATER COLLECTED, IMPINGERS & SILICA GEL	ml	167.2	173.9	172.0
V(w[gas])	VOLUME WATER VAPOR COLLECTED @ STANDARD CONDITIONS*	SCF (SCM)	7.892 (0.223)	8.208 (0.232)	8.118 (0.230)
%M	MOISTURE IN STACK GAS BY VOLUME	%	12.36	12.38	12.64
Md	MOL FRACTION OF DRY GAS		0.8764	0.8762	0.8736
Tt	NET TIME OF TEST	MINUTES	128	128	128

* 68 Deg.F, 29.92 "Hg (20 Deg.C, 760 mm Hg)

METCO ENVIRONMENTAL

SOURCE EMISSION CALCULATIONS

JOB NUMBER: 05-233
JOB NAME: ADA-ES
LOCATION: NEWARK, ARKANSAS
UNIT TESTED: UNIT NUMBER 2 ESP INLET DUCT - ONTARIO HYDRO

			RUN NUMBER		
SYMBOL	DESCRIPTION	UNITS	1	2	3
CO2		%	14.8	14.6	14.0
O2		%	5.4	5.8	4.8
CO		%	0.0	0.0	0.0
N2		%	79.8	79.6	81.2
%EA	EXCESS AIR @ SAMPLING POINT	%	34.3	37.9	28.7
MWd	MOLECULAR WEIGHT OF DRY STACK GAS	LB/LB-MOLE (g/g-MOLE)	30.58 (30.58)	30.57 (30.57)	30.43 (30.43)
MW	MOLECULAR WEIGHT OF STACK GAS	LB/LB-MOLE (g/g-MOLE)	29.03 (29.03)	29.01 (29.01)	28.86 (28.86)
Cp	PITOT TUBE CALIBRATION		0.816	0.816	0.816
DELTA P	VELOCITY HEAD OF STACK GAS	"H2O (mm H20)	0.983 (25.000)	0.966 (24.500)	0.937 (23.800)
DELTA P ^(1/2)		"H2O	0.982	0.972	0.953
Ts	STACK TEMPERATURE	DEG. F (DEG. C)	320 (160)	321 (161)	319 (159)
Ps	STACK PRESSURE	"Hg Abs. (mm Hg) "H20	28.73 (730.00) -14.10	28.62 (727.00) -14.10	28.60 (726.00) -14.50
Vs	STACK VELOCITY @ STACK CONDITIONS	FPM (m/SEC.)	3,971 (20)	3,942 (20)	3,871 (20)
As	STACK AREA	(SQ.INCHES) (SQ.METERS)	16,279 (11)	16,279 (11)	16,279 (11)
Qs	DRY STACK GAS VOLUME @ STANDARD CONDITIONS* WET STACK GAS VOLUME @ STANDARD CONDITIONS*	DSCFM (DSCM/HR) WSCFH	256,671 (436,084) 17,572,182	253,438 (430,591) 17,354,805	248,598 (422,368) 17,074,038
Qa	ACTUAL STACK GAS VOLUME @ STACK CONDITIONS	ACFM (m^3/HR)	448,864 (762,620)	445,585 (757,049)	437,601 (743,484)
Dn	SAMPLING NOZZLE DIAM.	IN. (m)	0.193 (0.005)	0.190 (0.005)	0.190 (0.005)
%I	PERCENT ISOKINETIC	%	95.1	103.2	101.6

* 68 Deg.F, 29.92 "Hg (20 Deg.C, 760 mm Hg)

SOURCE EMISSION SURVEY

JOB NUMBER: 05-233
JOB NAME: ADA-ES
LOCATION: NEWARK, ARKANSAS
UNIT TESTED: UNIT NUMBER 2 ESP OUTLET DUCT - METHODS 17 & 26A

SOURCE EMISSION CALCULATIONS

			RUN NUMBER		
SYMBOL	DESCRIPTION	UNITS	1	2	3
DATE			08/17/05	08/17/05	08/18/05
BEGIN TIME			1101	1802	1100
END TIME			1514	2048	1350
P(b)	BAROMETRIC PRESSURE	"Hg Abs. (mm Hg)	29.77 (756.00)	29.66 (753.00)	29.67 (754.00)
P(m)	ORIFICE PRESSURE DROP	"H2O (mm H2O)	1.095 (27.800)	0.873 (22.200)	1.068 (27.100)
	DGM CALIBRATION FACTOR		1.019	1.019	1.019
V(m)	VOLUME DRY GAS SAMPLED @ METER CONDITIONS LEAK CHECK VOLUME	ft.^3 (m^3) ft.^3	74.542 (2.111) 1.957	66.930 (1.895) 1.596	72.235 (2.045) 1.498
T(m)	AVERAGE GAS METER TEMPERATURE	DEG.F (DEG.C)	89 (32)	98 (37)	98 (37)
V(m[std])*	VOLUME DRY GAS SAMPLED @ STANDARD CONDITIONS*	DSCF (DSCM)	71.536 (2.026)	62.928 (1.782)	67.971 (1.925)
V(w)	TOTAL WATER COLLECTED, IMPINGERS & SILICA GEL	ml	203.7	168.7	199.1
V(w[gas])	VOLUME WATER VAPOR COLLECTED @ STANDARD CONDITIONS*	SCF (SCM)	9.615 (0.272)	7.963 (0.225)	9.398 (0.266)
%M	MOISTURE IN STACK GAS BY VOLUME	%	11.85	11.23	12.15
Md	MOL FRACTION OF DRY GAS		0.8815	0.8877	0.8785
Tt	NET TIME OF TEST	MINUTES	128	128	128

* 68 Deg.F, 29.92 "Hg (20 Deg.C, 760 mm Hg)

SOURCE EMISSION CALCULATIONS

JOB NUMBER: 05-233
JOB NAME: ADA-ES
LOCATION: NEWARK, ARKANSAS
UNIT TESTED: UNIT NUMBER 2 ESP OUTLET DUCT - METHODS 17 & 26A

			RUN NUMBER		
SYMBOL	DESCRIPTION	UNITS	1	2	3
CO2		%	12.8	13.6	13.2
O2		%	7.0	6.4	7.2
CO		%	0.0	0.0	0.0
N2		%	80.2	80.0	79.6
%EA	EXCESS AIR @ SAMPLING POINT	%	49.1	43.2	51.8
MWd	MOLECULAR WEIGHT OF DRY STACK GAS	LB/LB-MOLE (g/g-MOLE)	30.33 (30.33)	30.43 (30.43)	30.40 (30.40)
MW	MOLECULAR WEIGHT OF STACK GAS	LB/LB-MOLE (g/g-MOLE)	28.87 (28.87)	29.04 (29.04)	28.89 (28.89)
Cp	PITOT TUBE CALIBRATION		0.797	0.797	0.797
DELTA P	VELOCITY HEAD OF STACK GAS	"H2O (mm H20)	0.584 (14.800)	0.463 (11.800)	0.568 (14.400)
DELTA P ^(1/2)		"H2O	0.750	0.669	0.739
Ts	STACK TEMPERATURE	DEG. F (DEG. C)	298 (148)	324 (162)	312 (156)
Ps	STACK PRESSURE	"Hg Abs. (mm Hg) "H20	28.68 (728.00) -14.80	28.59 (726.00) -14.50	28.60 (726.00) -14.50
Vs	STACK VELOCITY @ STACK CONDITIONS	FPM (m/SEC.)	2,930 (15)	2,655 (13)	2,917 (15)
As	STACK AREA	(SQ.INCHES) (SQ.METERS)	21,024 (14)	21,024 (14)	21,024 (14)
Qs	DRY STACK GAS VOLUME @ STANDARD CONDITIONS* WET STACK GAS VOLUME @ STANDARD CONDITIONS*	DSCFM (DSCM/HR) WSCFH	252,709 (429,353) 17,200,839	222,254 (377,610) 15,022,237	245,498 (417,101) 16,767,080
Qa	ACTUAL STACK GAS VOLUME @ STACK CONDITIONS	ACFM (m^3/HR)	427,845 (726,909)	387,599 (658,531)	425,892 (723,591)
Dn	SAMPLING NOZZLE DIAM.	IN. (m)	0.247 (0.006)	0.247 (0.006)	0.247 (0.006)
%I	PERCENT ISOKINETIC	%	97.4	97.4	95.3

* 68 Deg.F, 29.92 "Hg (20 Deg.C, 760 mm Hg)

METCO ENVIRONMENTAL

SOURCE EMISSION CALCULATIONS

JOB NUMBER: 05-233
JOB NAME: ADA-ES
LOCATION: NEWARK, ARKANSAS
UNIT TESTED: UNIT NUMBER 2 ESP OUTLET DUCT - METHODS 17 & 26A

			RUN NUMBER		
SYMBOL	DESCRIPTION	UNITS	1	2	3
Mf	PARTICULATE - PROBE, CYCLONE AND FILTER	mg	47.4	50.3	55.8
Mt	PARTICULATE - TOTAL	mg	----	----	----
Can	PARTICULATE - PROBE, CYCLONE AND FILTER	gr/DSCF* (g/DSCM)	0.0102 (0.0234)	0.0123 (0.0282)	0.0126 (0.0290)
Cao	PARTICULATE - TOTAL	gr/DSCF* (g/DSCM)	---- ----	---- ----	---- ----
Cat	PARTIC.-PROBE, CYCLONE AND FILTER @ STACK COND.	gr/CF (g/m3)	0.0060 (0.0137)	0.0070 (0.0160)	0.0073 (0.0167)
Cau	PARTICULATE - TOTAL @ STACK CONDITIONS	gr/CF (g/m3)	---- ----	---- ----	---- ----
Caw	PARTICULATE - PROBE, CYCLONE AND FILTER	LBS/HR (Kg/HR)	22.10 (10.02)	23.45 (10.64)	26.60 (12.07)
Cax	PARTICULATE - TOTAL	LBS/HR (Kg/HR)	---- ----	---- ----	---- ----

* 68 Deg.F, 29.92 "Hg (20 Deg.C, 760 mm Hg)

METCO ENVIRONMENTAL

SOURCE EMISSION SURVEY

JOB NUMBER: 05-233
JOB NAME: ADA-ES
LOCATION: NEWARK, ARKANSAS
UNIT TESTED: UNIT NUMBER 2 ESP OUTLET DUCT - ONTARIO HYDRO

SOURCE EMISSION CALCULATIONS

SYMBOL	DESCRIPTION	UNITS	RUN NUMBER 1	2	3
DATE			08/17/05	08/17/05	08/18/05
BEGIN TIME			1110	1812	1120
END TIME			1443	2108	1403
P(b)	BAROMETRIC PRESSURE	"Hg Abs. (mm Hg)	29.77 (756.00)	29.66 (753.00)	29.67 (754.00)
P(m)	ORIFICE PRESSURE DROP	"H2O (mm H2O)	0.939 (23.900)	0.977 (24.800)	1.029 (26.100)
	DGM CALIBRATION FACTOR		0.999	0.999	0.999
V(m)	VOLUME DRY GAS SAMPLED @ METER CONDITIONS LEAK CHECK VOLUME	ft.^3 (m^3) ft.^3	55.380 (1.568) 4.833	72.282 (2.047) 8.558	72.749 (2.060) 8.679
T(m)	AVERAGE GAS METER TEMPERATURE	DEG.F (DEG.C)	88 (31)	101 (38)	102 (39)
V(m[std])*	VOLUME DRY GAS SAMPLED @ STANDARD CONDITIONS*	DSCF (DSCM)	53.223 (1.507)	67.614 (1.915)	67.961 (1.924)
V(w)	TOTAL WATER COLLECTED, IMPINGERS & SILICA GEL	ml	150.0	228.3	217.6
V(w[gas])	VOLUME WATER VAPOR COLLECTED @ STANDARD CONDITIONS*	SCF (SCM)	7.080 (0.200)	10.776 (0.305)	10.271 (0.291)
%M	MOISTURE IN STACK GAS BY VOLUME	%	11.74	13.75	13.13
Md	MOL FRACTION OF DRY GAS		0.8826	0.8625	0.8687
Tt	NET TIME OF TEST	MINUTES	96	128	128

* 68 Deg.F, 29.92 "Hg (20 Deg.C, 760 mm Hg)

METCO ENVIRONMENTAL

SOURCE EMISSION CALCULATIONS

JOB NUMBER: 05-233
JOB NAME: ADA-ES
LOCATION: NEWARK, ARKANSAS
UNIT TESTED: UNIT NUMBER 2 ESP OUTLET DUCT - ONTARIO HYDRO

			RUN NUMBER		
SYMBOL	DESCRIPTION	UNITS	1	2	3
CO2		%	12.8	13.6	13.2
O2		%	7.0	6.4	7.2
CO		%	0.0	0.0	0.0
N2		%	80.2	80.0	79.6
%EA	EXCESS AIR @ SAMPLING POINT	%	49.1	43.2	51.8
MWd	MOLECULAR WEIGHT OF DRY STACK GAS	LB/LB-MOLE (g/g-MOLE)	30.33 (30.33)	30.43 (30.43)	30.40 (30.40)
MW	MOLECULAR WEIGHT OF STACK GAS	LB/LB-MOLE (g/g-MOLE)	28.88 (28.88)	28.72 (28.72)	28.77 (28.77)
Cp	PITOT TUBE CALIBRATION		0.802	0.802	0.802
DELTA P	VELOCITY HEAD OF STACK GAS	"H2O (mm H20)	0.557 (14.100)	0.578 (14.700)	0.570 (14.500)
DELTA P ^(1/2)		"H2O	0.738	0.751	0.745
Ts	STACK TEMPERATURE	DEG. F (DEG. C)	325 (163)	343 (173)	330 (166)
Ps	STACK PRESSURE	"Hg Abs. (mm Hg) "H20	28.68 (728.00) -14.80	28.59 (726.00) -14.50	28.60 (726.00) -14.50
Vs	STACK VELOCITY @ STACK CONDITIONS	FPM (m/SEC.)	2,952 (15)	3,052 (16)	3,000 (15)
As	STACK AREA	(SQ.INCHES) (SQ.METERS)	21,024 (14)	21,024 (14)	21,024 (14)
Qs	DRY STACK GAS VOLUME @ STANDARD CONDITIONS* WET STACK GAS VOLUME @ STANDARD CONDITIONS*	DSCFM (DSCM/HR) WSCFH	246,156 (418,219) 16,733,923	242,361 (411,771) 16,859,896	243,978 (414,519) 16,851,249
Qa	ACTUAL STACK GAS VOLUME @ STACK CONDITIONS	ACFM (m^3/HR)	431,045 (732,345)	445,572 (757,027)	437,962 (744,097)
Dn	SAMPLING NOZZLE DIAM.	IN. (m)	0.247 (0.006)	0.247 (0.006)	0.247 (0.006)
%I	PERCENT ISOKINETIC	%	99.2	96.0	95.8

* 68 Deg.F, 29.92 "Hg (20 Deg.C, 760 mm Hg)

METCO ENVIRONMENTAL

APPENDIX C

Calibration Data

Equipment	Calibration Factor	Calibration Date
Pitot Tube #28-12-2	0.805	07/18/05
Pitot Tube #53-5-1 (low side)	0.806	07/21/05
Pitot Tube #53-5-2 (low side)	0.797	07/21/05
Pitot Tube #54-5-1 (low side)	0.816	06/23/05
Pitot Tube #54-5-2	0.802	06/23/05
Pitot Tube #54-10-1	0.806	06/23/05
Pitot Tube #54-12-1	0.808	07/05/05
Probe Tip #05-233-1	0.247	08/16/05
Probe Tip #05-233-3	0.247	08/16/05
Probe Tip #05-233-4	0.193	08/16/05
Probe Tip #05-233-5	0.190	08/16/05
Probe Tip #05-233-7	0.190	08/16/05
Dry Gas Meter #28-2	1.019	07/07/05
Stack Unit Orifice #28-2		07/08/05
Digital Temperature Indicator #28-2		07/07/05
Dry Gas Meter #28-3	1.008	06/24/05
Stack Unit Orifice #28-3		07/07/05
Digital Temperature Indicator #28-3		06/24/05
Dry Gas Meter #53-1	0.997	07/01/05
Stack Unit Orifice #53-1		07/05/05
Digital Temperature Indicator #53-1		07/01/05

APPENDIX C

Calibration Data

Equipment	Calibration Factor	Calibration Date
Dry Gas Meter #53-2	0.999	07/12/05
Stack Unit Orifice #53-2		07/12/05
Digital Temperature Indicator #53-2		07/12/05
Barometer #53-3		07/08/05

PITOT TUBE CALIBRATION

Date: 7/18/05 Time: 1500

Pitot No.: 28-12-2 T_s: 75 °F

Pitot Dimensions: 12' x 3/8" C_{pstd}: 0.990

Motor Setting	fps mark	Calibration Standard Start	Calibration Standard End	√Standard Average	High	√High	Cal. Factor	Low	√Low	Cal. Factor
7	20	0.10	0.10	0.316	0.15	0.387	0.808	0.15	0.387	0.808
14	30	0.22	0.22	0.469	0.33	0.574	0.808	0.33	0.574	0.808
20	40	0.34	0.34	0.583	0.52	0.721	0.801	0.52	0.721	0.801
28	50	0.54	0.54	0.735	0.83	0.911	0.799	0.83	0.911	0.799
35	60	0.80	0.80	0.894	1.20	1.095	0.808	1.20	1.095	0.808
41	70	1.00	1.00	1.000	1.50	1.225	0.808	1.50	1.225	0.808
50	80	1.30	1.30	1.140	2.00	1.414	0.798	2.00	1.414	0.798
62	90	1.60	1.60	1.265	2.40	1.549	0.808	2.40	1.549	0.808
28	50	0.54	0.54	0.735	0.83	0.911	0.799	0.83	0.911	0.799
28	50	0.54	0.54	0.735	0.83	0.911	0.799	0.83	0.911	0.799
Average							0.805			0.805

Summary of Results:

Normal high side calibration factor 0.805

variation + 0.37 %

variation - 0.87 %

Normal low side calibration factor 0.805

variation + 0.37 %

variation - 0.87 %

Calibrator: [signature]

Checked By: [signature]

PITOT TUBE CALIBRATION

Date: 7-21-05 Time: 0945

Pitot No.: 53-5-1 T_s: 75 °F

Pitot Dimensions: 5' X 1/4" C_{pstd}: 0.990

Motor Setting	fps mark	Calibration Standard Start	Calibration Standard End	$\sqrt{\text{Standard Average}}$	High	$\sqrt{\text{High}}$	Cal. Factor	Low	$\sqrt{\text{Low}}$	Cal. Factor
7	20	0.10	0.10	0.316	0.15	0.387	0.808	0.15	0.387	0.808
14	30	0.22	0.22	0.469	0.33	0.574	0.808	0.34	0.583	0.796
20	40	0.34	0.34	0.583	0.51	0.714	0.808	0.51	0.714	0.808
28	50	0.54	0.54	0.735	0.80	0.894	0.813	0.80	0.894	0.813
35	60	0.80	0.80	0.894	1.20	1.095	0.808	1.20	1.095	0.808
41	70	1.00	1.00	1.000	1.50	1.225	0.808	1.50	1.225	0.808
50	80	1.30	1.30	1.140	2.00	1.414	0.798	2.00	1.414	0.798
62	90	1.60	1.60	1.265	2.40	1.549	0.808	2.40	1.549	0.808
28	50	0.54	0.54	0.735	0.80	0.894	0.813	0.80	0.894	0.813
28	50	0.54	0.54	0.735	0.80	0.894	0.813	0.80	0.894	0.813
Average							0.807			0.806

Summary of Results:

Normal high side calibration factor 0.807 ✓

variation + 0.74% ✓

variation - 1.12% ✓

Normal low side calibration factor 0.806 ✓

variation + 0.87% ✓

variation - 1.24% ✓

Calibrator: [signature]

Checked By: JASON BROWN

PITOT TUBE CALIBRATION

Date: 7-21-05 Time: 0820

Pitot No.: 53-5-2 T_s: 75 °F

Pitot Dimensions: 5' X 1/4" C_{pstd}: 0.990

Motor Setting	fps mark	Calibration Standard Start	Calibration Standard End	$\sqrt{\text{Standard Average}}$	High	$\sqrt{\text{High}}$	Cal. Factor	Low	$\sqrt{\text{Low}}$	Cal. Factor
7	20	0.10	0.10	0.316	0.15	0.387	0.808	0.15	0.387	0.808
14	30	0.22	0.22	0.469	0.34	0.583	0.796	0.34	0.583	0.796
20	40	0.34	0.34	0.583	0.51	0.714	0.808	0.51	0.714	0.808
28	50	0.54	0.54	0.735	0.82	0.906	0.803	0.83	0.911	0.799
35	60	0.80	0.80	0.894	1.25	1.118	0.792	1.25	1.118	0.792
41	70	1.00	1.00	1.000	1.55	1.245	0.795	1.55	1.245	0.795
50	80	1.30	1.30	1.140	2.00	1.414	0.798	2.05	1.432	0.788
62	90	1.60	1.60	1.265	2.45	1.565	0.800	2.50	1.581	0.792
28	50	0.54	0.54	0.735	0.82	0.906	0.803	0.83	0.911	0.799
28	50	0.54	0.54	0.735	0.82	0.906	0.803	0.83	0.911	0.799
Average							0.800			0.797

Summary of Results:

Normal high side calibration factor 0.800 ✓

variation + 1.00 ✓

variation - 1.00 ✓

Normal low side calibration factor 0.797 ✓

variation + 1.38 ✓

variation - 1.13 ✓

Calibrator: [signature]

Checked By: Jason Brown

PITOT TUBE CALIBRATION

Date: 23 June 2005 Time: 1500

Pitot No.: 54-5-1 T_s: 78 °F

Pitot Dimensions: 5' x 1/4" C_{pstd}: 0.990

Motor Setting	fps mark	Calibration Standard Start	Calibration Standard End	$\sqrt{\text{Standard Average}}$	High	$\sqrt{\text{High}}$	Cal. Factor	Low	$\sqrt{\text{Low}}$	Cal. Factor
7	20	0.10	0.10	0.316	0.15	0.387	0.808	0.15	0.387	0.808
14	30	0.22	0.22	0.469	0.33	0.574	0.808	0.32	0.566	0.821
20	40	0.34	0.34	0.583	0.50	0.707	0.816	0.50	0.707	0.816
28	50	0.54	0.54	0.735	0.80	0.894	0.813	0.80	0.894	0.813
35	60	0.80	0.80	0.894	1.20	1.095	0.808	1.15	1.072	0.826
41	70	1.00	1.00	1.000	1.50	1.225	0.808	1.45	1.204	0.822
50	80	1.30	1.30	1.140	1.95	1.396	0.808	1.90	1.396	0.808
62	90	1.60	1.60	1.265	2.35	1.533	0.817	2.35	1.533	0.817
28	50	0.54	0.54	0.735	0.80	0.894	0.813	0.80	0.894	0.813
28	50	0.54	0.54	0.735	0.80	0.894	0.813	0.80	0.894	0.813
Average							0.811			0.816

Summary of Results:

Normal high side calibration factor 0.811

variation + 0.74%

variation - 0.37%

Normal low side calibration factor 0.816

variation + 1.23%

variation - 0.98%

Calibrator: Ned Shappley

Checked By: Jason Brown

PITOT TUBE CALIBRATION

Date: 23 June 2005
Time: 1430
Pitot No.: 54-5-2
T_s: 77 °F
Pitot Dimensions: 5' X 1/4"
C_{pstd}: 0.990

Motor Setting	fps mark	Calibration Standard Start	Calibration Standard End	$\sqrt{\text{Standard Average}}$	High	$\sqrt{\text{High}}$	Cal. Factor	Low	$\sqrt{\text{Low}}$	Cal. Factor
7	20	0.10	0.10	0.316	0.15	0.387	0.808	0.15	0.387	0.808
14	30	0.22	0.22	0.469	0.33	0.574	0.808	0.33	0.574	0.808
20	40	0.34	0.34	0.583	0.52	0.721	0.801	0.51	0.714	0.808
28	50	0.54	0.54	0.735	0.82	0.906	0.803	0.82	0.906	0.803
35	60	0.80	0.80	0.894	1.25	1.118	0.792	1.20	1.095	0.808
41	70	1.00	1.00	1.000	1.55	1.245	0.795	1.55	1.245	0.795
50	80	1.30	1.30	1.140	1.95	1.396	0.808	1.95	1.396	0.808
62	90	1.60	1.60	1.265	2.45	1.565	0.800	2.40	1.549	0.808
28	50	0.54	0.54	0.735	0.82	0.906	0.803	0.82	0.906	0.803
28	50	0.54	0.54	0.735	0.82	0.906	0.803	0.82	0.906	0.803
Average							0.802			0.806

Summary of Results:

Normal high side calibration factor 0.802
variation + 0.75%
variation - 1.25%
Normal low side calibration factor 0.806
variation + 0.25%
variation - 1.36%

Calibrator: Ned Shappley

Checked By: JASON BROWN

PITOT TUBE CALIBRATION

Date: 23 June 2005

Time: 1400

Pitot No.: 54-10-1

T_s: 77 °F

Pitot Dimensions: 10' X 3/8"

C_{pstd}: 0.990

Motor Setting	fps mark	Calibration Standard Start	Calibration Standard End	$\sqrt{\text{Standard Average}}$	High	$\sqrt{\text{High}}$	Cal. Factor	Low	$\sqrt{\text{Low}}$	Cal. Factor
7	20	0.10	0.10	0.316	0.15	0.387	0.808	0.15	0.387	0.808
14	30	0.22	0.22	0.469	0.33	0.574	0.808	0.33	0.574	0.808
20	40	0.34	0.34	0.583	0.51	0.714	0.808	0.51	0.714	0.808
28	50	0.54	0.54	0.735	0.81	0.900	0.808	0.81	0.900	0.808
35	60	0.80	0.80	0.894	1.20	1.095	0.808	1.20	1.095	0.808
41	70	1.00	1.00	1.000	1.55	1.245	0.795	1.55	1.245	0.795
50	80	1.30	1.30	1.140	1.95	1.396	0.808	1.95	1.396	0.808
62	90	1.60	1.60	1.265	2.40	1.549	0.808	2.40	1.549	0.808
28	50	0.54	0.54	0.735	0.81	0.900	0.808	0.81	0.900	0.808
28	50	0.54	0.54	0.735	0.81	0.900	0.808	0.81	0.900	0.808
Average							0.806			0.806

Summary of Results:

Normal high side calibration factor 0.806

variation + 0.25%

variation - 1.36%

Normal low side calibration factor 0.806

variation + 0.25%

variation - 1.36%

Calibrator: Ned Shappley

Checked By: JASON BROWN

PITOT TUBE CALIBRATION

Date: 7/5/05

Time: 0930

Pitot No.: 54-12-1

T_s: 77 °F

Pitot Dimensions: 12 x 3/8"

C_{pstd}: 0.990

Motor Setting	fps mark	Calibration Standard Start	Calibration Standard End	$\sqrt{\text{Standard Average}}$	High	$\sqrt{\text{High}}$	Cal. Factor	Low	$\sqrt{\text{Low}}$	Cal. Factor
7	20	0.10	0.10	0.316	0.15	0.387	0.808	0.15	0.387	0.808
14	30	0.22	0.22	0.469	0.33	0.574	0.808	0.33	0.574	0.808
20	40	0.34	0.34	0.583	0.51	0.714	0.808	0.51	0.714	0.808
28	50	0.54	0.54	0.735	0.81	0.900	0.808	0.80	0.894	0.813
35	60	0.80	0.80	0.894	1.20	1.095	0.808	1.20	1.095	0.808
41	70	1.00	1.00	1.000	1.50	1.225	0.808	1.50	1.225	0.808
50	80	1.30	1.30	1.140	1.95	1.396	0.808	1.90	1.378	0.819
62	90	1.60	1.60	1.265	2.40	1.549	0.808	2.45	1.565	0.800
28	50	0.54	0.54	0.735	0.81	0.900	0.808	0.80	0.894	0.813
28	50	0.54	0.54	0.735	0.81	0.900	0.808	0.80	0.894	0.813
Average										

Summary of Results:

Normal high side calibration factor 0.808 ✓

variation + 0.00%

variation - 0.00%

Normal low side calibration factor 0.809 ✓

variation + 1.24%

variation - 1.11%

Calibrator: Ned Shappley

Checked By: Jason Brown

METCO ENVIRONMENTAL

NOZZLE CALIBRATION

Nozzle Set No. 05-233 TASK 1

Date 8-16-05 Calibrator: Malone

	05-233-1	05-233-2	05-233-3	05-233-4	05-233-5	05-233-6
Reading 1	0.247	0.246	0.246	0.193	0.190	0.190
Reading 2	0.247	0.245	0.247	0.193	0.190	0.190
Reading 3	0.246	0.247	0.246	0.193	0.191	0.191
Reading 4	0.247	0.245	0.247	0.194	0.189	0.190
Reading 5	0.246	0.245	0.247	0.194	0.190	0.190
Reading 6	0.248	0.245	0.247	0.193	0.190	0.189
Reading 7	0.248	0.247	0.246	0.193	0.190	0.191
Reading 8	0.247	0.246	0.247	0.194	0.190	0.190
Reading 9	0.247	0.246	0.247	0.192	0.190	0.190
Reading 10	0.247	0.246	0.247	0.193	0.190	0.190
Average	0.247	0.246	0.247	0.193	0.190	0.190

	05-233-7	05-233-8	9	10	11	12
Reading 1	0.190	0.245				
Reading 2	0.190	0.248				
Reading 3	0.191	0.247				
Reading 4	0.189	0.247				
Reading 5	0.191	0.246				
Reading 6	0.189	0.248				
Reading 7	0.190	0.247				
Reading 8	0.190	0.247				
Reading 9	0.190	0.246				
Reading 10	0.190	0.247				
Average	0.190	0.247				

Dry Gas Meter Calibration

Dry Gas Meter No.: 28-2

Date: 7/7/05

ΔH ("H_2O)	C_{DG}
0.5	1.020
1.0	1.011
1.5	1.035
2.0	1.028
3.0	1.010
4.0	1.012
Average	1.019

Variation: + 1.57%

\- 0.88%

Calibrator: Ned Shappley

Checked By: [signature]

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 28-2 Calibrator: Ned Shappley

Date: 7/7/05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 0.5" H_2O

P_b: 29.37 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4) / Dry Gas Meter

	Wet Test Meter: Time	Meter Reading	Temp.	P_m	Dry Gas Meter: Meter Reading	Temp. In	Temp. Out	P_m
End	1508	6.820 cf	75 °F	-0.5 "H_2O	500.430 cf	81 °F	73 °F	0.50 "H_2O
Start	1452	0.000 cf	75 °F	-0.5 "H_2O	493.718 cf	76 °F	73 °F	0.50 "H_2O
Avg.		6.820 cf	75 °F	-0.5 "H_2O	6.712 cf	76	°F	0.50 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 6.820 \left[\frac{29.37 + \frac{-0.5}{13.6}}{75 + 460}\right] \times 1.004 \; (C_t) = 6.626 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 6.712 \left[\frac{29.37 + \frac{0.50}{13.6}}{76 + 460}\right] = 6.499 \text{ dcsf}$$

$$C_{DG} = \frac{6.626}{6.499} = \boxed{1.020}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 28.2　　　Calibrator: Ned Shappley

Date: 7/7/05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 1.0" H_2O　　　P_b: 29.37 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4)　　　**Dry Gas Meter**

	Time	Meter Reading		Temp.		P_m		Meter Reading		Temp. In		Temp. Out		P_m	
End	1528	8.195	cf	75	°F	-0.90	"H_2O	508.743	cf	85	°F	74	°F	1.0	"H_2O
Start	1514	0.000	cf	75	°F	-0.90	"H_2O	500.600	cf	78	°F	73	°F	1.0	"H_2O
Avg.		8.195	cf	75	°F	-0.90	"H_2O	8.143	cf	78			°F	1.0	"H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 8.195 \left[\frac{29.37 + \frac{-0.90}{13.6}}{75 + 460} \right] \times 1.004 \ (C_f) = 7.954 \ dcsf$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 8.143 \left[\frac{29.37 + \frac{1.0}{13.6}}{78 + 460} \right] = 7.866 \ dcsf$$

$$C_{DG} = \frac{7.954}{7.866} = \boxed{1.011}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 28-3

Calibrator: Ned Shappley

Date: 7/7/05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 1.5" H_2O

P_b: 29.37 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4)

	Time	Meter Reading	Temp.	P_m
End	1552	12.485 cf	75 °F	-1.30 "H_2O
Start	1535	0.000 cf	75 °F	-1.30 "H_2O
Avg.		12.485 cf	75 °F	-1.30 "H_2O

Dry Gas Meter

	Meter Reading	Temp. In	Temp. Out	P_m
End	521.019 cf	88 °F	75 °F	1.50 "H_2O
Start	508.875 cf	81 °F	74 °F	1.50 "H_2O
Avg.	12.144 cf	80 °F		1.50 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 12.485 \left[\frac{29.37 + \frac{-1.30}{13.6}}{75 + 460} \right] \times 1.004 \; (C_f) = 12.106 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 12.144 \left[\frac{29.37 + \frac{1.50}{13.6}}{80 + 460} \right] = 11.702 \text{ dcsf}$$

$$C_{DG} = \frac{12.106}{11.702} = \boxed{1.035}$$

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 28-3 Calibrator: Ned Shappley

Date: 7/7/05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 20" H_2O

P_b: 29.37 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4) | **Dry Gas Meter**

	Time	Meter Reading		Temp.		P_m		Meter Reading		Temp. In		Temp. Out		P_m	
End	1614	14.500	cf	75	°F	-1.800	"H_2O	535.823	cf	92	°F	76	°F	2.0	"H_2O
Start	1555	0.000	cf	75	°F	-1.800	"H_2O	521.607	cf	86	°F	75	°F	2.0	"H_2O
Avg.		14.500	cf	75	°F	-1.800	"H_2O	14.216	cf	82			°F	2.0	"H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 14.500 \left[\frac{29.37 + \frac{-1.80}{13.6}}{75 + 460}\right] \times 1.004 \ (C_t) = 14.042 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 14.216 \left[\frac{29.37 + \frac{2.0}{13.6}}{82 + 460}\right] = 13.665 \text{ dcsf}$$

$$C_{DG} = \frac{14.042}{13.665} = \boxed{1.028}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 28-2

Calibrator: Ned Shappley

Date: 7/7/05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 3.0" H_2O

P_b: 29.37 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4) — Dry Gas Meter

	Time	Meter Reading		Temp.		P_m		Meter Reading		Temp. In		Temp. Out		P_m	
End	1635	14.100	cf	75	°F	-2.7	"H_2O	550.089	cf	92	°F	78	°F	3.0	"H_2O
Start	1618	0.000	cf	75	°F	-2.7	"H_2O	536.071	cf	87	°F	76	°F	3.0	"H_2O
Avg.		14.100	cf	75	°F	-2.7	"H_2O	14.018	cf	83			°F	3.0	"H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 14.100 \left[\frac{29.37 + \frac{-2.7}{13.6}}{75 + 460}\right] \times 1.004 \ (C_t) = 13.624 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 14.018 \left[\frac{29.37 + \frac{3.0}{13.6}}{83 + 460}\right] = 13.483 \text{ dcsf}$$

$$C_{DG} = \frac{13.624}{13.483} = \boxed{1.010}$$

VERSION 1
22 OCTOBER 2002

DRY GAS METER CALIBRATION

Meter Number: 28-2 Calibrator: Ned Shappley

Date: 7-7-05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 4.0

P_b: 29.37 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4) — **Dry Gas Meter**

	Wet Test Meter Time	Wet Test Meter Meter Reading	Wet Test Meter Temp.	Wet Test Meter P_m	Dry Gas Meter Meter Reading	Dry Gas Meter Temp. In	Dry Gas Meter Temp. Out	Dry Gas Meter P_m
End	1650	12.130 cf	75 °F	-3.80 "H_2O	562.306 cf	92 °F	79 °F	4.0 "H_2O
Start	1640	0.000 cf	75 °F	-3.80 "H_2O	550.302 cf	88 °F	77 °F	4.0 "H_2O
Avg.		12.130 cf	75 °F	-3.80 "H_2O	12.004 cf	84 °F		4.0 "H_2O

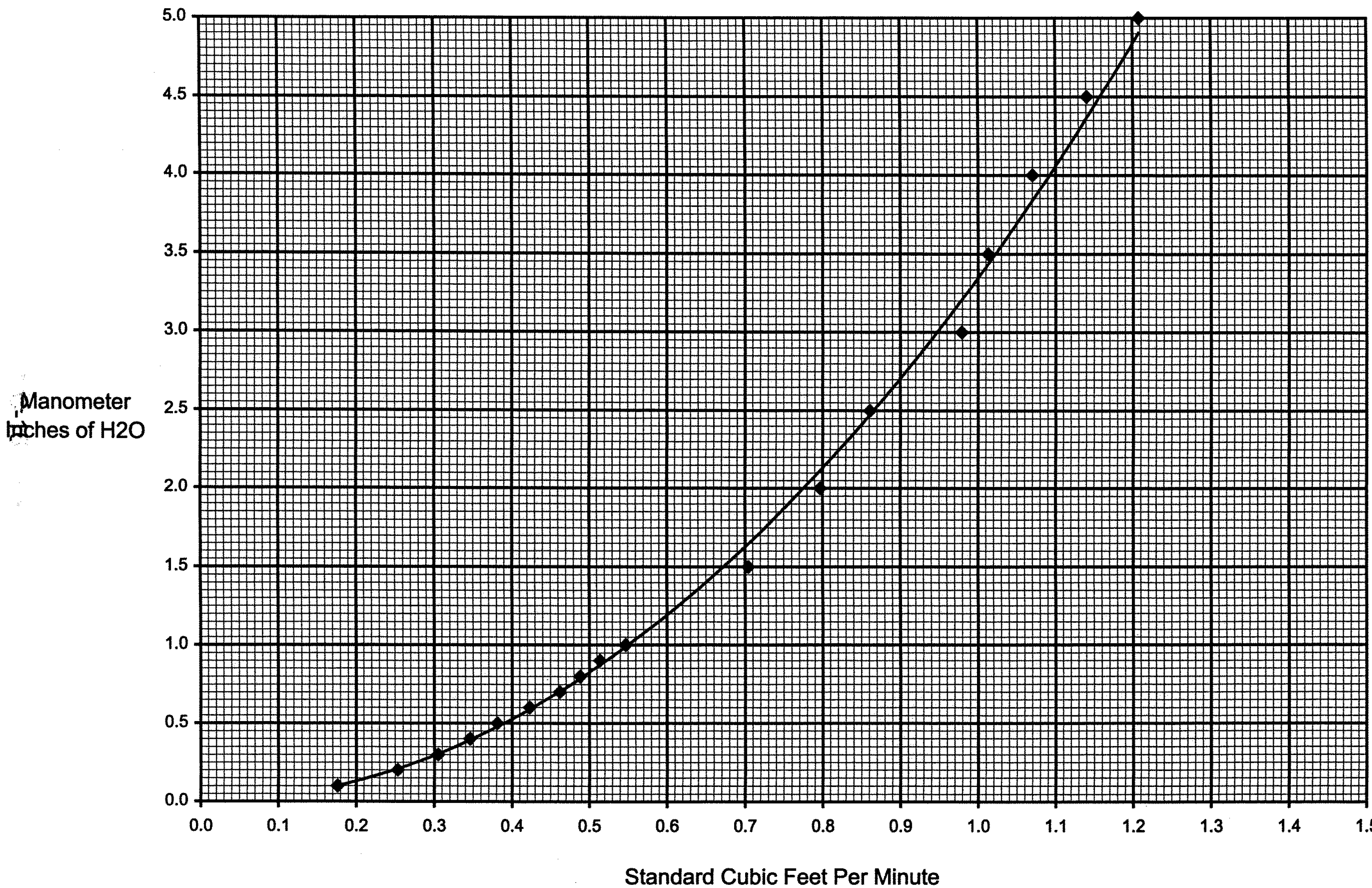
$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 12.130 \left[\frac{29.37 + \frac{-3.80}{13.6}}{75 + 460}\right] \times 1.004 \quad (C_f) = 11.688 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 12.004 \left[\frac{29.37 + \frac{4.0}{13.6}}{84 + 460}\right] = 11.553 \text{ dcsf}$$

$$C_{DG} = \frac{11.688}{11.553} = \boxed{1.012}$$

VERSION 1
22 OCTOBER 2002

STACK UNIT ORIFICE NO: **28-2** DATE: **07/08/05** CALIBRATED BY: **Ned Shappley** CHECKED BY:



METCO ENVIRONMENTAL

DIGITAL TEMPERATURE INDICATOR NO. 28-2

CALIBRATION DATA

DATE: 7/7/05

Media	Time	Mercury Temperature (°F)	DTI (°F)
Ambient Air	1415	74	74
Ice Bath	1421	32	33
Boiling Water	1424	211	210
Oven	1450	250	251
Oven	1442	300	301
Oven	1431	350	351
Oven	1436	375	376

Meter Adjusted? YES ______ No ✓

Reference Thermometer No. 01

Calibrator Ned Shappley

Checked By: [signature]

VERSION 2
15 APRIL 2004

METCO ENVIRONMENTAL

Dry Gas Meter Calibration

Dry Gas Meter No.: 28-3

Date: 6-24-2005

ΔH ("H_2O)	C_{DG}
0.5	1.015
1.0	1.028
1.5	1.010
2.0	1.007
3.0	0.999
4.0	0.989
Average	1.008

Variation: + 1.98%

\- 1.88%

Calibrator: Doug Ware

Checked By: Ned Shappley

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 28-3

Calibrator: Doug Ware

Date: 6/24/05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 0.5" H_2O

P_b: 29.41 "Hg

Control Module Vacuum: 5 "Hg

Wet Test Meter (No. 3) | Dry Gas Meter

	Time	Meter Reading	Temp.	P_m	Meter Reading	Temp. In	Temp. Out	P_m
End	1029	5.085 cf	77 °F	-1.1 "H_2O	31.534 cf	80 °F	80 °F	0.50 "H_2O
Start	1016	0.000 cf	77 °F	-1.1 "H_2O	26.531 cf	80 °F	80 °F	0.50 "H_2O
Avg.	13	5.085 cf	77 °F	-1.1 "H_2O	5.003 cf	80 °F		0.50 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 5.085 \left[\frac{29.41 \quad \frac{-1.1}{13.6}}{77 + 460} \right] \times .997\ (C_t) = 4.887 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 5.003 \left[\frac{29.41 + \frac{.50}{13.6}}{80 + 460} \right] = 4.815 \text{ dcsf}$$

$$C_{DG} = \frac{4.887}{4.815} = \boxed{1.015}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 28-3

Calibrator: Doug Ware

Date: 6/24/05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 1.0 "H_2O

P_b: 29.41 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 3) — **Dry Gas Meter**

	Time	Meter Reading	Temp.	P_m	Meter Reading	Temp. In	Temp. Out	P_m
End	1100	6.248 cf	77 °F	-1.7 "H_2O	41.551 cf	84 °F	78 °F	1.00 "H_2O
Start	1046	0.000 cf	77 °F	-1.7 "H_2O	35.499 cf	81 °F	78 °F	1.00 "H_2O
Avg.	14	6.248 cf	77 °F	-1.7 "H_2O	6.052 cf	80	°F	1.00 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 6.248 \left[\frac{29.41 + \frac{-1.7}{13.6}}{77 + 460} \right] \times .997\ (C_f) = 5.995 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 6.052 \left[\frac{29.41 + \frac{1.00}{13.6}}{80 + 460} \right] = 5.832 \text{ dcsf}$$

$$C_{DG} = \frac{5.995}{5.832} = \boxed{1.028}$$

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 28.3 Calibrator: Doug Ware

Date: 6/24/05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1@ 1.5 " H_2O P_b: 29.41 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 3) — Dry Gas Meter

	Wet Test Meter: Time	Meter Reading	Temp.	P_m	Dry Gas Meter: Meter Reading	Temp. In	Temp. Out	P_m
End	1121	11.251 cf	77 °F	-2.30 "H_2O	54.001 cf	88 °F	78 °F	1.50 "H_2O
Start	1104	0.000 cf	77 °F	-2.30 "H_2O	42.922 cf	81 °F	77 °F	1.50 "H_2O
Avg.	17	11.251 cf	77 °F	-2.30 "H_2O	11.079 cf	81	°F	1.50 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 11.251 \left[\frac{29.41 + \frac{-2.30}{13.6}}{77 + 460} \right] \times .997 \ (C_t) = 10.781 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 11.079 \left[\frac{29.41 + \frac{1.50}{13.6}}{81 + 460} \right] = 10.670 \text{ dcsf}$$

$$C_{DG} = \frac{10.781}{10.670} = \boxed{1.010}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 28-3

Calibrator: Doug Ware

Date: 6/24/05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 2.0 " H_2O

P_b: 29.41 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 3) | **Dry Gas Meter**

	Wet Test Meter Time	Wet Test Meter Meter Reading	Wet Test Meter Temp.	Wet Test Meter P_m	Dry Gas Meter Meter Reading	Dry Gas Meter Temp. In	Dry Gas Meter Temp. Out	Dry Gas Meter P_m
End	1143	11.151 cf	77 °F	-2.90 "H_2O	65.879 cf	85 °F	79 °F	2.00 "H_2O
Start	1128	0.000 cf	77 °F	-2.90 "H_2O	54.877 cf	84 °F	78 °F	2.00 "H_2O
Avg.		11.151 cf	77 °F	-2.90 "H_2O	cf		°F	"H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 11.151 \left[\frac{29.41 + \frac{-2.90}{13.6}}{77 + 460}\right] \times .997 \ (C_t) = 10.669 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 11.002 \left[\frac{29.41 + \frac{2.00}{13.6}}{82 + 460}\right] = 10.590 \text{ dcsf}$$

$$C_{DG} = \frac{10.669}{10.590} = \boxed{1.007}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 28-3

Date: 6/24/05

Calibrator: Doug Ware

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 3.0" H2O

P_b: 29.41 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 3) | Dry Gas Meter

	Time	Meter Reading	Temp.	P_m	Meter Reading	Temp. In	Temp. Out	P_m
End	1525	11.221 cf	77 °F	-4.2 "H_2O	105.946 cf	81 °F	75 °F	3.0 "H_2O
Start	1511	0.000 cf	77 °F	-4.2 "H_2O	94.945 cf	75 °F	75 °F	3.0 "H_2O
Avg.		11.221 cf	77 °F	-4.2 "H_2O	11.001 cf	77	°F	3.0 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 11.221 \left[\frac{29.41 + \frac{-4.2}{13.6}}{77 + 460} \right] \times .997 \; (C_f) = 10.701 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 11.001 \left[\frac{29.41 + \frac{3.0}{13.6}}{77 + 460} \right] = 10.714 \text{ dcsf}$$

$$C_{DG} = \frac{10.701}{10.714} = \boxed{0.999}$$

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 28-3

Date: 6/24/05

Calibrator: Doug Ware

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 4.0" H_2O

P_b: 29.41 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 3)

	Time	Meter Reading	Temp.	P_m
End	1339	15.197 cf	77 °F	-6.0 "H_2O
Start	1327	0.000 cf	77 °F	-6.0 "H_2O
Avg.	12	15.197 cf	77 °F	-6.0 "H_2O

Dry Gas Meter

	Meter Reading	Temp. In	Temp. Out	P_m
End	93.544 cf	87 °F	77 °F	4.0 "H_2O
Start	78.527 cf	78 °F	76 °F	4.0 "H_2O
Avg.	15.017 cf	80 °F		4.0 "H_2O

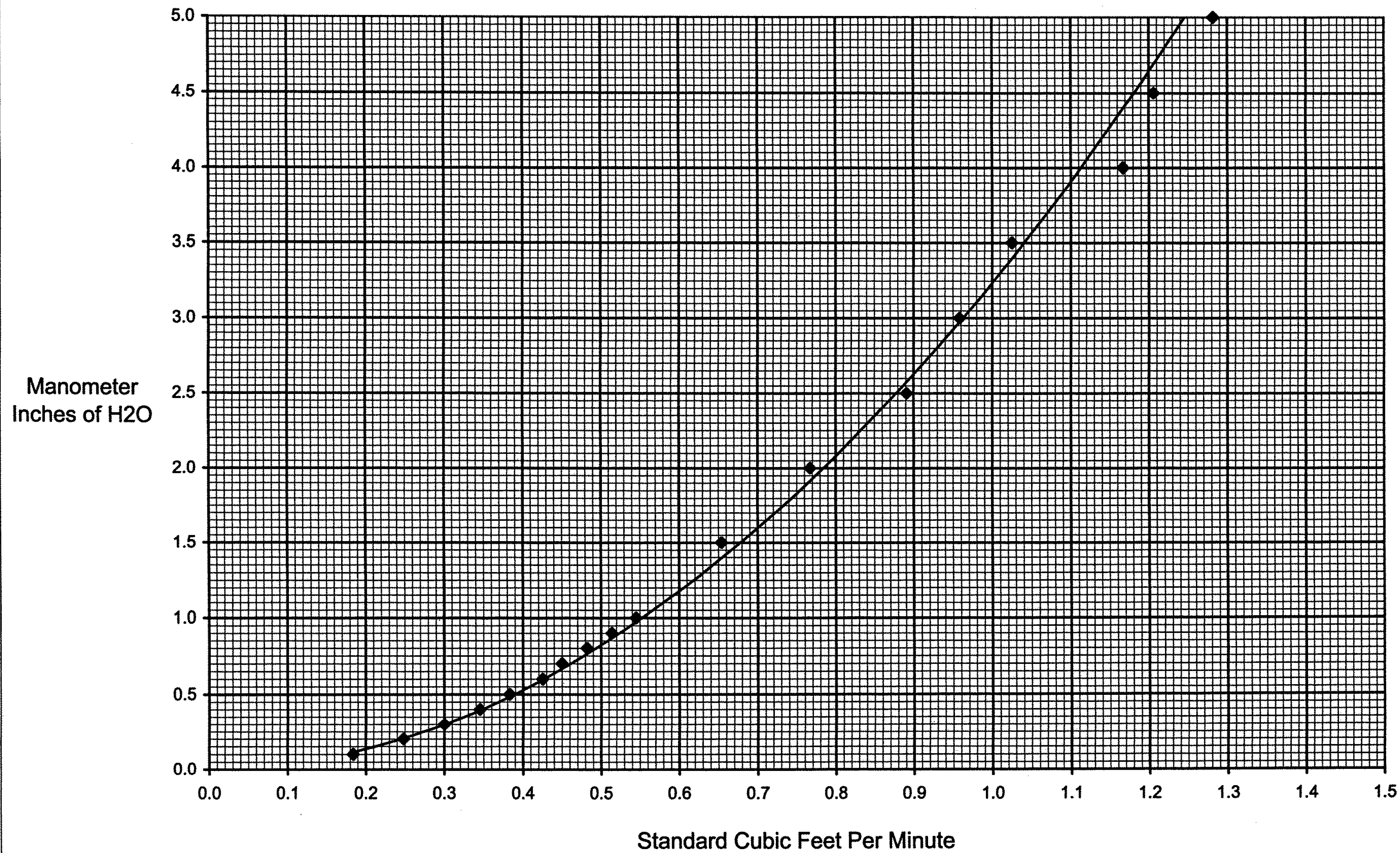
$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 15.197 \left[\frac{29.41 + \frac{-6.0}{13.6}}{77 + 460} \right] \times .997 \; (C_t) = 14.426 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 15.017 \left[\frac{29.41 + \frac{4.0}{13.6}}{80 + 460} \right] = 14.580 \text{ dcsf}$$

$$C_{DG} = \frac{14.427}{14.580} = \boxed{0.989}$$

VERSION 1
22 OCTOBER 2002

STACK UNIT ORIFICE NO: **28-3** DATE: **07/07/05** CALIBRATED BY: **Ned Shappley** CHECKED BY:



METCO ENVIRONMENTAL

DIGITAL TEMPERATURE INDICATOR NO. 28-3

CALIBRATION DATA

DATE: 6-24-2005

Media	Time	Mercury Temperature (°F)	DTI (°F)
Ambient Air	847	72	70
Ice Bath	845	31	32
Boiling Water	859	211	209
Oven	917	253	250
Oven	939	300	300
Oven	955	351	350
Oven	1004	375	375

Meter Adjusted? YES ______ No ______

Reference Thermometer No. D.1

Calibrator Doug Ware

Checked By: Mark Glica

VERSION 2
15 APRIL 2004

METCO ENVIRONMENTAL

Dry Gas Meter Calibration

Dry Gas Meter No.: 53-1

Date: 07-01-05

ΔH ("H_2O)	C_{DG}
0.5	0.983
1.0	0.990
1.5	0.998
2.0	0.996
3.0	1.010
4.0	1.007
Average	0.997

Variation: + 1.30%
- 1.40 %

Calibrator: [signature]

Checked By: Steve Bowser

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-1   Calibrator: Mitchell Stuckert

Date: 07-01-05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 0.5 P_b: 29.29 "Hg

Control Module Vacuum: 5 "Hg

Wet Test Meter (No. 3)   **Dry Gas Meter**

	Time	Meter Reading	Temp.	P_m	Meter Reading	Temp. In	Temp. Out	P_m
End	11:40	5.173 cf	75 °F	1.50 "H_2O	121.858 cf	77 °F	77 °F	0.50 "H_2O
Start	0:00	0.000 cf	75 °F	1.50 "H_2O	116.588 cf	75 °F	74 °F	0.50 "H_2O
Avg.	11:40	5.173 cf	75 °F	1.50 "H_2O	5.270 cf	76 °F		0.50 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 5.173 \left[\frac{29.29 + \frac{1.500}{13.6}}{75 + 460}\right] \times 0.997 (C_f) = 5.002 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 5.270 \left[\frac{29.29 + \frac{0.500}{13.6}}{76 + 460}\right] = 5.089 \text{ dcsf}$$

$$C_{DG} = \frac{5.002}{5.089} = \boxed{0.983}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-1

Calibrator: [signature]

Date: 07-01-05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 1.0

P_b: 29.27 "Hg

Control Module Vacuum: 5 "Hg

Wet Test Meter (No. 3) — Dry Gas Meter

	Time	Meter Reading	Temp.	P_m	Meter Reading	Temp. In	Temp. Out	P_m
End	8:35	5.210 cf	75 °F	2.0 "H_2O	128.228 cf	80 °F	77 °F	1.00 "H_2O
Start	0:00	0.000 cf	75 °F	2.0 "H_2O	122.933 cf	78 °F	77 °F	~~1.00~~ 1.00 "H_2O
Avg.	8:35	5.218 cf	75 °F	2.0 "H_2O	5.295 cf	78 °F		1.00 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 5.218 \left[\frac{29.29 + \frac{2.00}{13.6}}{75 + 460}\right] \times 0.997\ (C_f) = 5.052 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 5.295 \left[\frac{29.29 + \frac{1.00}{13.6}}{78 + 460}\right] = 5.101 \text{ dcsf}$$

$$C_{DG} = \frac{5.052}{5.101} = \boxed{0.990}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-1

Date: 07-01-05

Calibrator: [signature]

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 1.5

P_b: 29.29 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 3)

Dry Gas Meter

	Time	Meter Reading	Temp.	P_m	Meter Reading	Temp. In	Temp. Out	P_m
End	14:04	10.161 cf	76 °F	2.20 "H_2O	139.031 cf	84 °F	79 °F	1.50 "H_2O
Start	0:00	0.000 cf	76 °F	2.20 "H_2O	128.784 cf	79 °F	76 °F	1.50 "H_2O
Avg.	14:04	10.161 cf	76 °F	2.20 "H_2O	10.247 cf	80 °F		"H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 10.161 \left[\frac{29.29 + \frac{2.200}{13.6}}{76 + 460}\right] \times 0.997\ (C_t) = 9.825 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 10.247 \left[\frac{29.29 + \frac{1.500}{13.6}}{80 + 460}\right] = 9.847 \text{ dcsf}$$

$$C_{DG} = \frac{9.825}{9.847} = \boxed{0.998}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-1

Calibrator: [signature]

Date: 07-01-05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 2.0

P_b: 29.29 "Hg

Control Module Vacuum: 5 "Hg

Wet Test Meter (No. 3) — **Dry Gas Meter**

	Wet Test Meter: Time	Meter Reading	Temp.	P_m	Dry Gas Meter: Meter Reading	Temp. In	Temp. Out	P_m
End	12:25	10.397 cf	77 °F	3.30 "H_2O	150.218 cf	89 °F	80 °F	2.00 "H_2O
Start	0:00	0.002 cf	77 °F	3.30 "H_2O	139.667 cf	84 °F	78 °F	2.00 "H_2O
Avg.	12:25	10.341 cf	77 °F	3.30 "H_2O	10.551 cf	83 °F		2.00 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 10.341 \left[\frac{29.29 + \frac{3.30}{13.6}}{77 + 460}\right] \times 0.997 (C_f) = 10.056 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 10.551 \left[\frac{29.29 + \frac{2.00}{13.6}}{83 + 460}\right] = 10.096 \text{ dcsf}$$

$$C_{DG} = \frac{10.056}{10.096} = \boxed{\cancel{0.40}\ 0.996}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-1

Calibrator: [signature]

Date: 07-01-05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 3.0

P_b: 29.29 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 3) | **Dry Gas Meter**

	Time	Meter Reading	Temp.	P_m	Meter Reading	Temp. In	Temp. Out	P_m
End		9.608 cf	77 °F	4.50 "H_2O	161.533 cf	93 °F	79 °F	3.00 "H_2O
Start	0:00	0.000 cf	77 °F	4.50 "H_2O	151.869 cf	88 °F	78 °F	3.00 "H_2O
Avg.		9.608 cf	77 °F	4.50 "H_2O	9.664 cf	85 °F		3.00 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 9.608 \left[\frac{29.29 + \frac{4.500}{13.6}}{77 + 460}\right] \times 0.997 (C_t) = 9.326 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 9.664 \left[\frac{29.29 + \frac{3.000}{13.6}}{85 + 460}\right] = 9.236 \text{ dcsf}$$

$$C_{DG} = \frac{9.326}{9.236} = \boxed{1.010}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-1

Calibrator: [signature]

Date: 07-01-05

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 4.0

P_b: 29.29 "Hg

Control Module Vacuum: 5 "Hg

Wet Test Meter (No. 3) | **Dry Gas Meter**

	Wet Test Meter Time	Wet Test Meter Meter Reading	Wet Test Meter Temp.	Wet Test Meter P_m	Dry Gas Meter Meter Reading	Dry Gas Meter Temp. In	Dry Gas Meter Temp. Out	Dry Gas Meter P_m
End	8:45	10.440 cf	77 °F	6.00 "H_2O	172.397 cf	79 °F	78 °F	4.00 "H_2O
Start	0:00	0.000 cf	77 °F	6.00 "H_2O	162.993 cf	77 °F	77 °F	4.00 "H_2O
Avg.	8:45	10.440 cf	77 °F	6.00 "H_2O	10.404 cf	78 °F		"H_2O

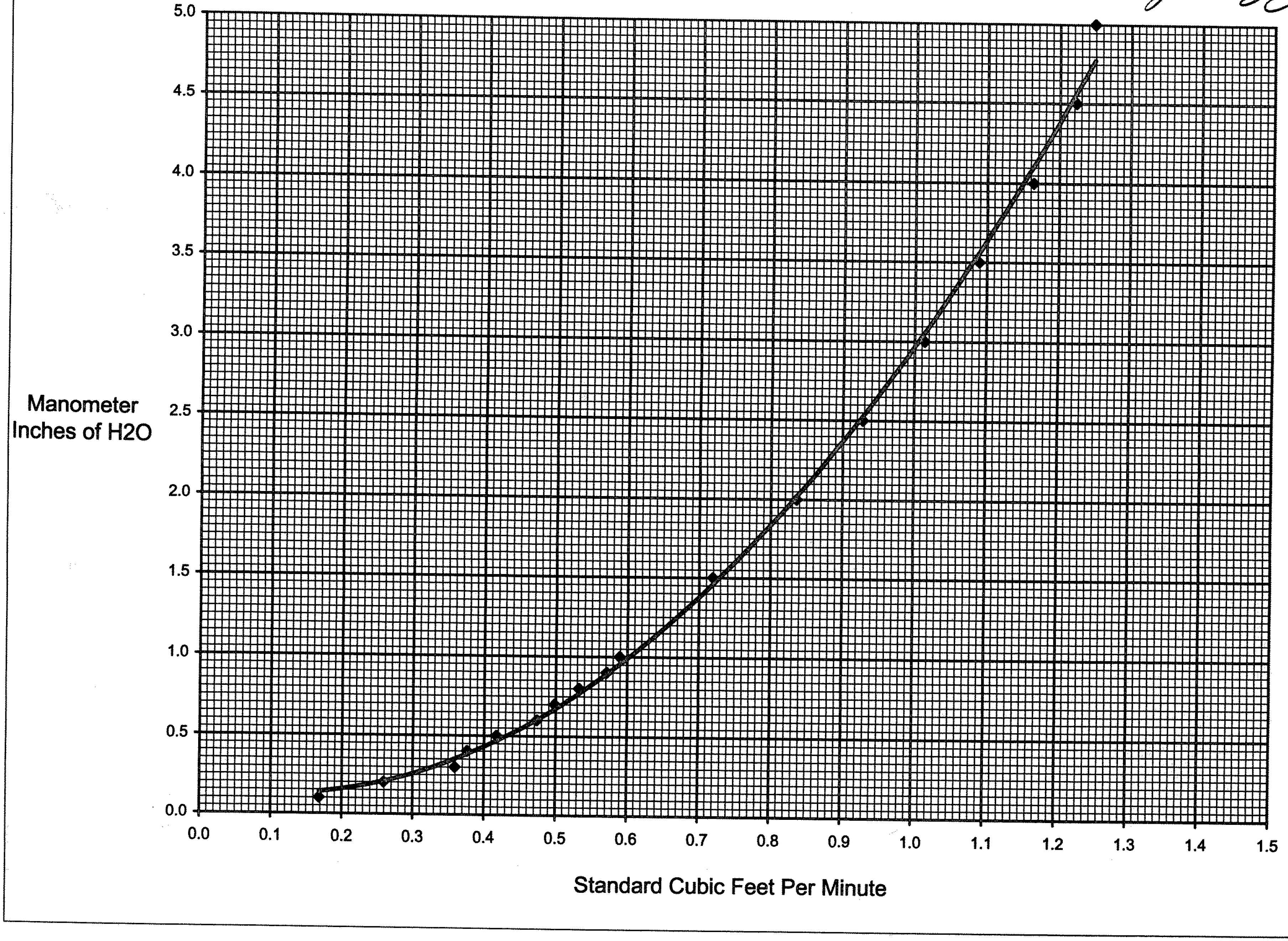
$$\text{Wet Test Meter } Vm_{std} = 17.65 \; x \, 10.440 \left[\frac{29.29 + \frac{6.000}{13.6}}{77 + 460} \right] x \, 0.997 \, (C_f) = 10.171 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \; x \, 10.404 \left[\frac{29.29 + \frac{4.000}{13.6}}{78 + 460} \right] = 10.098 \text{ dcsf}$$

$$C_{DG} = \frac{10.171}{10.097} = \boxed{1.007}$$

VERSION 1
22 OCTOBER 2002

Orifice # 53-1   Calibrated By: Mitchell Stuckert   Date 7-5-05   Checked By: [signature]



METCO ENVIRONMENTAL

DIGITAL TEMPERATURE INDICATOR NO. 53-1

CALIBRATION DATA

DATE: 07-01-05

Media	Time	Mercury Temperature (°F)	DTI (°F)
Ambient Air	9:02	76	76
Ice Bath	9:05	32	32
Boiling Water	9:08	212	213
Oven	9:12	251	253
Oven	9:29	372	373
Oven	9:38	353	352
Oven	9:49	306	305

Meter Adjusted? YES ______ No ✓

Reference Thermometer No. D-1

Calibrator [signature]

Checked By: Steve Borensen

VERSION 2
15 APRIL 2004

Dry Gas Meter Calibration

Dry Gas Meter No.: 53-2

Date: 12 July 2005

ΔH ("H_2O)	C_{DG}
0.5	1.008
1.0	1.003
1.5	0.997
2.0	0.997
3.0	0.993
4.0	0.995
Average	0.999

Variation: + 0.9%
- 0.50%

Calibrator: Phil Rowland

Checked By: Ned Shappley

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-2

Date: 12 July 2006

Calibrator: Phil Rowland

$$\textit{Calibration Factor } (C_{DG}) = \frac{\textit{Wet Test Meter } Vm_{std}}{\textit{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 0.50

P_b: 29.38 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4) | Dry Gas Meter

	Time	Meter Reading	Temp.	P_m	Meter Reading	Temp. In	Temp. Out	P_m
End	0906	5.020 cf	77 °F	-0.60 "H_2O	378.249 cf	90 °F	81 °F	0.50 "H_2O
Start	0854	0.000 cf	77 °F	-0.60 "H_2O	373.188 cf	88 °F	81 °F	0.50 "H_2O
Avg.		5.020 cf	77 °F	-0.60 "H_2O	5.061 cf	85 °F		0.50 "H_2O

$$\textit{Wet Test Meter } Vm_{std} = 17.65 \times 5.020 \left[\frac{29.38 + \frac{-0.60}{13.6}}{77 + 460}\right] \times 1.004\ (C_t) = 4.860 \text{ dcsf}$$

$$\textit{Dry Gas Meter } Vm_{std} = 17.65 \times 5.061 \left[\frac{29.38 + \frac{0.50}{13.6}}{85 + 460}\right] = 4.821 \text{ dcsf}$$

$$C_{DG} = \frac{4.860}{4.821} = \boxed{1.008}$$

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-2

Date: 12 July 2005

Calibrator: Phil Rowland

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 1.00

P_b: 29.38 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4) — **Dry Gas Meter**

	Wet Test Meter: Time	Meter Reading	Temp.	P_m	Dry Gas Meter: Meter Reading	Temp. In	Temp. Out	P_m
End	0920	5.020 cf	77 °F	-1.00 "H_2O	384.972 cf	90 °F	81 °F	1.00 "H_2O
Start	0912	0.000 cf	77 °F	-1.00 "H_2O	379.896 cf	89 °F	81 °F	1.00 "H_2O
Avg.		5.020 cf	77 °F	-1.00 "H_2O	5.076 cf	85 °F		1.00 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 5.020 \left[\frac{29.38 + \frac{-1.00}{13.6}}{77 + 460}\right] \times 1.004\,(C_f) = 4.855 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 5.076 \left[\frac{29.38 + \frac{1.00}{13.6}}{85 + 460}\right] = 4.842 \text{ dcsf}$$

$$C_{DG} = \frac{4.855}{4.842} = \boxed{1.003}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-2

Calibrator: Phil Rowland

Date: 12 July 2005

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 1.50

P_b: 29.38 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4)

Dry Gas Meter

	Time	Meter Reading	Temp.	P_m	Meter Reading	Temp. In	Temp. Out	P_m
End	0940	10.095 cf	77 °F	-1.35 "H_2O	396.550 cf	95 °F	82 °F	1.50 "H_2O
Start	0926	0.000 cf	77 °F	-1.30 "H_2O	386.271 cf	90 °F	81 °F	1.50 "H_2O
Avg.		10.095 cf	77 °F	-1.33 "H_2O	10.279 cf		87 °F	1.50 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 10.095 \left[\frac{29.38 + \frac{-1.33}{13.6}}{77 + 460} \right] \times 1.004\ (C_t) = 9.755 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 10.279 \left[\frac{29.38 + \frac{1.50}{13.6}}{87 + 460} \right] = 9.781 \text{ dcsf}$$

$$C_{DG} = \frac{9.755}{9.781} = \boxed{0.997}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-2

Calibrator: Phil Rowland

Date: 12 July 2005

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 2.00

P_b: 29.38 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4) | **Dry Gas Meter**

	Time	Meter Reading	Temp.	P_m	Meter Reading	Temp. In	Temp. Out	P_m
End	0958	10.100 cf	77 °F	-1.70 "H_2O	407.408 cf	100 °F	82 °F	2.00 "H_2O
Start	0946	0.000 cf	77 °F	-1.65 "H_2O	397.101 cf	92 °F	82 °F	2.00 "H_2O
Avg.		10.100 cf	77 °F	-1.68 "H_2O	10.307 cf	89 °F		2.00 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 10.100 \left[\frac{29.38 + \frac{-1.68}{13.6}}{77 + 460}\right] \times 1.004\ (C_f) = 9.751 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 10.307 \left[\frac{29.38 + \frac{2.00}{13.6}}{89 + 460}\right] = 9.784 \text{ dcsf}$$

$$C_{DG} = \frac{9.751}{9.784} = \boxed{0.997}$$

VERSION 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-2

Calibrator: Phil Rowland

Date: 12 July 2005

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 3.00

P_b: 29.38 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4)

Dry Gas Meter

	Wet Test Meter: Time	Meter Reading	Temp.	P_m	Dry Gas Meter: Meter Reading	Temp. In	Temp. Out	P_m
End	1011	10.100 cf	77 °F	-2.45 "H_2O	418.711 cf	100 °F	83 °F	3.00 "H_2O
Start	1001	0.000 cf	77 °F	-2.40 "H_2O	408.379 cf	97 °F	82 °F	3.00 "H_2O
Avg.		10.100 cf	77 °F	-2.43 "H_2O	10.332 cf	91 °F		3.00 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 10.100 \left[\frac{29.38 + \frac{-2.43}{13.6}}{77 + 460}\right] \times 1.004\ (C_t) = 9.733 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 10.332 \left[\frac{29.38 + \frac{3.00}{13.6}}{91 + 460}\right] = 9.797 \text{ dcsf}$$

$$C_{DG} = \frac{9.733}{9.797} = \boxed{0.993}$$

METCO ENVIRONMENTAL

DRY GAS METER CALIBRATION

Meter Number: 53-2 Calibrator: Phil Rowland

Date: 12 July 2005

$$\text{Calibration Factor } (C_{DG}) = \frac{\text{Wet Test Meter } Vm_{std}}{\text{Dry Gas Meter } Vm_{std}}$$

Run No.: 1 @ 4.00

P_b: 29.38 "Hg

Control Module Vacuum: 5.0 "Hg

Wet Test Meter (No. 4) **Dry Gas Meter**

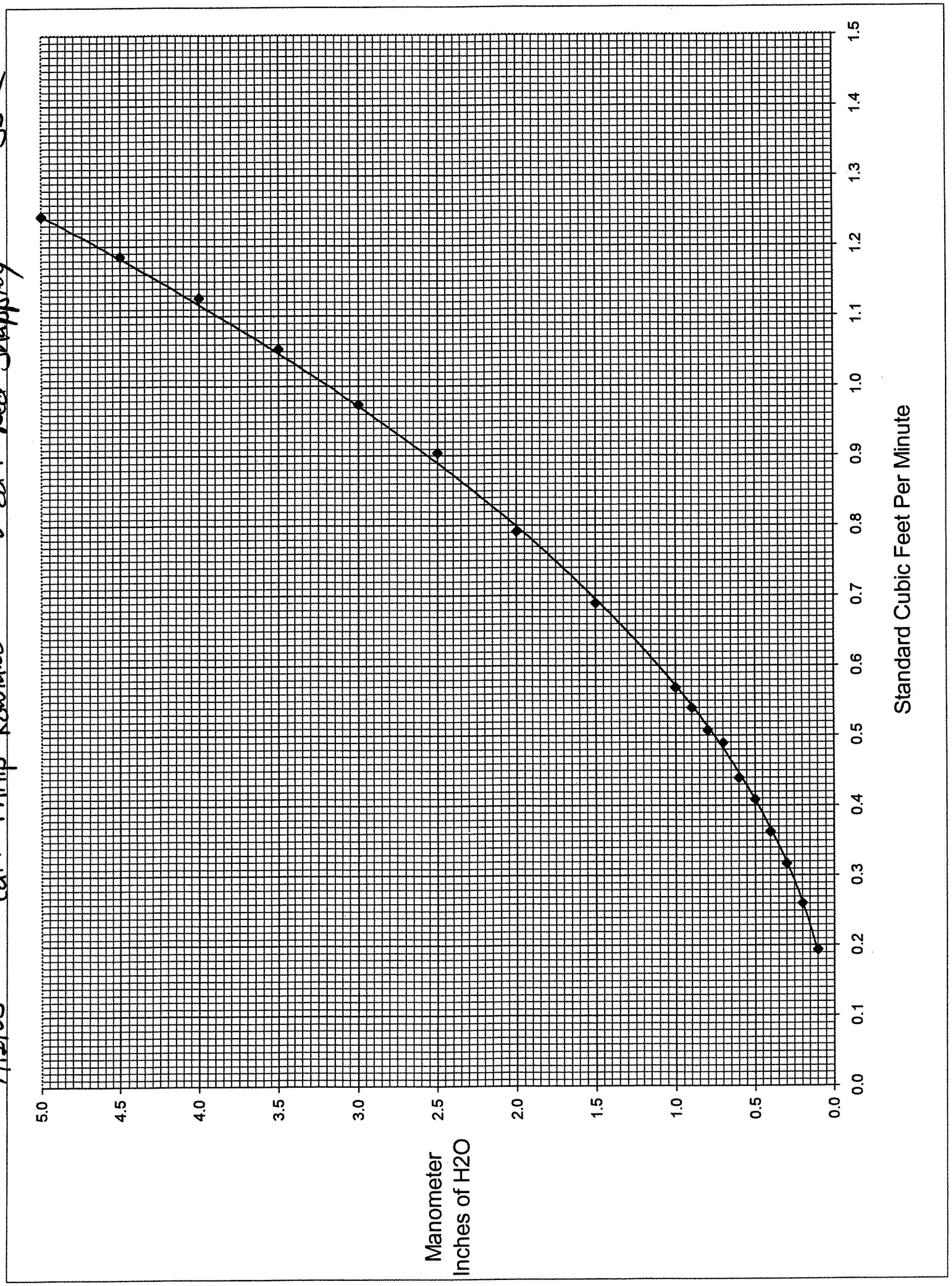
	Time	Meter Reading	Temp.	P_m	Meter Reading	Temp. In	Temp. Out	P_m
End	1025	10.115 cf	77 °F	-3.20 "H_2O	430.333 cf	107 °F	85 °F	4.00 "H_2O
Start	1016	0.000 cf	77 °F	-3.10 "H_2O	419.988 cf	98 °F	84 °F	4.00 "H_2O
Avg.		10.115 cf	77 °F	-3.15 "H_2O	10.345 cf	94 °F		4.00 "H_2O

$$\text{Wet Test Meter } Vm_{std} = 17.65 \times 10.115 \left[\frac{29.38 + \frac{-3.15}{13.6}}{77 + 460}\right] \times 1.004\ (C_f) = 9.729 \text{ dcsf}$$

$$\text{Dry Gas Meter } Vm_{std} = 17.65 \times 10.345 \left[\frac{29.38 + \frac{4.00}{13.6}}{94 + 460}\right] = 9.780 \text{ dcsf}$$

$$C_{DG} = \frac{9.729}{9.780} = \boxed{0.995}$$

VERSION 1
22 OCTOBER 2002


7/12/05
cal: Philip Rowland
✓ed: Ned Shappley
53-2
Manometer
Inches of H2O
Standard Cubic Feet Per Minute
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5

METCO ENVIRONMENTAL

DIGITAL TEMPERATURE INDICATOR NO. 53-2

CALIBRATION DATA

DATE: 12 July 2005

Media	Time	Mercury Temperature (°F)	DTI (°F)
Ambient Air	0820	80	78
Ice Bath	0825	33	33
Boiling Water	0827	212	212
Oven	0840	250	250
Oven	0842	298	300
Oven	0844	348	350
Oven	0845	372	375

Meter Adjusted? YES ______ No ✓

Reference Thermometer No. D-1

Calibrator Phil Rowland

Checked By: Ned Shappley

METCO ENVIRONMENTAL

JMG 54

BAROMETER CALIBRATION

Barometer No. 53-3

Date: 163 07/08/05

Time: 1632

Barometric Pressure @ Addison Airport @ 719 ft.	=	29.97
	-	0.719
Absolute Pressure @ Addison Airport	=	29.251
	+	0.083
Absolute Pressure @ METCO @ 636 ft.	=	29.334
Barometer Reading	=	29.33
Variation	=	0.004
Barometer Adjusted?	Yes ____	No ✓
Barometer Reading (after adjustment)	=	

Signature of Calibrator

APPENDIX D

Field Testing Data

METCO ENVIRONMENTAL

Job Number: 05-233 TASK 1 ✓ — 178126A — Field Data

Job Name: ADA-ES ✓

Run Number: 1 ✓

Unit: Unit 2 ESP Inlet Duct ✓

Date: 8-17-05 ✓

Operator: Simpson / Ware / Bornsen ✓

Sample box No. 51-2 Meter Box No. 531 ✓

Read and record at the start of each test point.

Purge to: —

Purge time: —

Pitot Leak Check Initial ✓ Final ✓ ✓

Ambient Temp. °F: 88°

Assumed Moisture %: 12

Probe Length: 5'

C Factor: 0.485 to reference.

Initial Leak @ 15.0 "Hg = 0.000 cfm ✓

Final Leak @ 6.0 "Hg = 0.000 cfm ✓

Point	Clock Time (1103)	Dry Gas Meter, CF (532.979)	ΔP_s "Pitot" "H_2O	Orifice ΔH "H_2O Desired	P_m Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
12-4	~~1103~~	~~532.607~~	1.05	0.51	0.51	3.0	338	285	274	50	84	82	Pb = 29.78
3	1107	534.98	1.10	0.53	0.53	3.0	338	273	272	50	83	83	Ps = ~~-14.1~~
2	1111	536.78	1.20	0.58	0.58	3.0	339	279	279	51	85	83	-14.9
1	1115	538.74	1.20	0.58	0.58	3.0	341	279	280	50	84	82	
End	1119	540.431	—	—	—	—	—	—	—	—	—	—	vol = .492 ✓
11-4	1120	540.923	1.05	0.51	0.51	3.0	338	278	277	48	84	84	
3	1124	542.82	0.94	0.46	0.46	3.0	339	285	282	52	86	83	
2	1128	544.43	0.89	0.43	0.43	3.0	341	279	277	53	87	83	
1	1132	546.09	0.81	0.39	0.39	3.0	339	283	276	53	86	82	
End	1134	547.545	—	—	—	—	—	—	—	—	—	—	vol = 0.400 ✓
10-4	1156	547.945	0.94	0.46	0.46	3.0	342	270	281	57	86	85	
3	1200	549.84	1.10	0.53	0.53	3.0	342	279	280	55	86	85	
2	1204	551.63	0.94	0.46	0.46	3.0	342	274	285	51	86	85	
1	1208	553.49	0.94	0.46	0.46	3.0	338	283	284	53	87	85	
End	1212	554.812	—	—	—	—	—	—	—	—	—	—	vol = 0.528 ✓
8-4	1236	555.340	0.57	0.28	0.28	2.0	331	279	287	55	85	84	
3	1240	556.81	0.42	0.20	0.20	2.0	331	270	280	55	85	85	
2	1244	557.96	0.27	0.13	0.13	2.0	332	274	274	56	85	86	

Pitot Tube Calibration Factor C_p: 0.806 ✓ low side

Volume Collected V_m: ~~57.256~~ ft^3 57.402 ✓

Water Collected V_w: 166.8 ✓ ml

Time of Test T_t: 128 ✓ min.

Stack Pressure P_s: -14.90 ✓ "H_2O

Pitot Tube No. 53-5-1 ✓

Baro. Press. P_b: 29.76 ✓ "Hg

Probe Tip Dia. D_n: 0.190 ✓ in.

% CO_2: 14.8 ✓ % CO: 0.0 ✓

% O_2: 5.4 ✓ % N_2: 79.8 ✓

Area Stack A_s: ~~21,024~~ 16,279 ✓ in^2

Barometer No. 53-3 ✓ Probe Tip No. 05-233-7 ✓

Total Volume of Leak Checks After Start: ~~3.475~~ ft^3 3.338 ✓

V_m = Dry Gas Meter Calibration Factor ~~57.428~~ x 0.997 ✓ 57.575

{Dry Gas Meter Reading — ft^3 – (T_t — min. X Leak Rate — cfm)}

VERSION 1
22 OCTOBER 2002

Impinger Box No. 51.2

			Water Weight Gain	
Impinger 1	Final Weight	878.0	Impinger 1	140.7
	Initial Weight	737.3		
	Increase		Impinger 2	14.1
Impinger 2	Final Weight	769.7		
	Initial Weight	755.6	Impinger 3	1.7
	Increase		Impinger 4	0.3
Impinger 3	Final Weight	638.0	Impinger 5	1.7
	Initial Weight	636.3		
	Increase		Impinger 6	8.3
Impinger 4	Final Weight	744.3	Impinger 7	
	Initial Weight	744.0		
	Increase		Total	166.8 ✓ = V_w
Impinger 5	Final Weight	736.7		
	Initial Weight	735.0		
	Increase			
Impinger 6	Final Weight	919.6		
	Initial Weight	911.3		
	Increase			
Impinger 7	Final Weight			
	Initial Weight			
	Increase			

V_w =
$g\ SO_2$ = -
V_w =

P_b = 29.76 ✓		$\%CO_2$ = 14.8 ✓	
V_m = ~~57.256~~ 57.402 ✓		$\%O_2$ = 5.4 ✓	
V_w = 166.8 ✓		$\%CO$ = 0.0 ✓	
P_m = 0.544 ✓		$\%N_2$ = 79.8 ✓	
Avg ΔP = 1.032 ✓		A_s = ~~21.024~~ 16.279 ✓	
		D_n = 0.190 ✓	
Avg$\sqrt{\Delta P}$ = 1.002 ✓		T_t = 128 ✓	
C_p = 0.806 ✓			
P_s = -14.1 ✓ "H_2O		28.72 ✓ "Hg	
T_m = ~~90~~ 88 °F		~~550~~ 548 ✓ °R	
T_s = 329 ✓ °F		789 ✓ °R	

Moisture Content: %M = ~~12.57~~ 12.50 ✓ M_d = ~~0.8743~~ 0.8750 ✓ MW_d = 30.584 ✓ MW = ~~29.00~~ 29.01 ✓

$$Vm_{std} = 17.65\ Vm\left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times \cancel{57.256}\ 57.402 \left[\frac{29.76 + \frac{0.544}{13.6}}{\cancel{90}\ 88 + 460}\right] = \frac{\cancel{54.754}\ 55.094\ \text{sft}^3}{\cancel{0.428}\ 0.430\ \text{scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x 166.8 ✓ = 7.873 ✓ sft^3

$$\%\ Moisture = \frac{Vw_{gas}}{Vm_{std} + Vw_{gas}} \times 100 = \frac{7.873}{\cancel{54.754}\ 55.094 + 7.873} \times 100 = \cancel{12.57}\ 12.50\ \%$$

$$V_s = 5123.8 \times 0.806 \sqrt{\frac{789}{28.72 \times \cancel{29.00}\ 29.01}} \times 1.002 = \cancel{4028}\ 4{,}027\ \text{fpm}$$

$$\%I = \frac{1{,}039 \times \cancel{54.754}\ 55.094 \times 789}{128 \times \cancel{0.8743}\ 0.8750 \times \cancel{4028}\ 4027 \times 28.72 \times (0.190)^2} = \cancel{96.0}\ 96.6\ \%$$

ACFM: ~~588024~~ 455,232 ✓

SCFM: ~~331496~~ 256,821 ✓

%EA: 34.3 ✓

VERSION 1
22 OCTOBER 2002

Run Number 1
Unit Unit 2 ES Inlet Duct
Date 8-17-05

118/26A **FIELD DATA**

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	Orifice ΔH "H_2O Desired	P_m Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
4-1	1248	558.84	6.30	0.15	0.15	2.0	333	279	275	60	86	85	leak ✓ @ 6.0 = 0.000
End	1252	559.862	-	-	-	-	-	-	-	-	-	-	Vol = 0.410
4-4	1409	560.272	1.10	0.61	0.61	3.0	325	274	253	68	88	87	Pb = 29.75
3	1413	562.21	1.25	0.70	0.70	4.0	324	282	254	64	89	89	Psz -14.0
2	1417	564.22	1.25	0.70	0.70	4.0	327	280	256	55	91	89	C7 = 0.557
1	1421	566.29	1.10	0.61	0.61	4.0	327	270	256	54	92	89	
End	1425	568.215	-	-	-	-	-	-	-	-	-	-	vol = 0.539
3-4	1426	568.754	1.10	0.61	0.61	4.0	324	276	257	51	92	89	
3	1430	570.71	1.10	0.61	0.61	4.0	322	264	254	52	93	89	
2	1434	572.78	1.20	0.67	0.67	4.0	325	275	261	54	93	90	
1	1438	574.82	1.10	0.61	0.61	4.0	306	282	262	54	95	90	
End	1442	576.584	-	-	-	-	-	-	-	-	-	-	vol = 0.539
2-4	1443	577.123	1.20	0.67	0.67	4.0	323	279	262	49	95	89	
3	1447	579.10	1.10	0.61	0.61	4.0	321	283	262	49	96	91	
2	1451	581.06	1.00	0.56	0.56	4.0	322	280	267	50	96	91	
1	1455	583.01	1.10	0.61	0.61	4.0	322	277	267	52	97	92	
End	1459	584.895	-	-	-	-	-	-	-	-	-	-	vol = 0.420
1-4	1600	585.315	1.40	0.78	0.78	5.0	308	281	268	50	96	92	
3	1604	587.26	1.50	0.83	0.83	5.0	310	270	264	51	97	92	
2	1608	589.34	1.50	0.83	0.83	5.0	310	279	268	53	97	92	
1	1612	591.45	1.30	0.73	0.73	5.0	311	281	269	53	98	93	
End	1616	593.882	-	-	-	-	-	-	-	-	-	-	

METCO ENVIRONMENTAL

Job Number 05-233-TASK1 ✓ M~~17~~126A Field Data
Job Name ADA-ES ✓
Run Number 2 ✓
Unit ESP Inlet ~~Exhaust~~ Duct ✓
Date 8-17-05 ✓
Operator Simpson/Orr/Bornser
Sample box No. 51-1 Meter Box No. 53-1 ✓

Read and record at the start of each test point.

Purge to: –
Purge time: –
Pitot Leak Check Initial ✓ Final ✓ ✓

Ambient Temp. °F 92
Assumed Moisture % 12%
Probe Length 5'
C Factor 0.557 to reference.
Initial Leak @ 15.0"Hg = 0.000 cfm ✓
Final Leak @ 8.0"Hg = 0.000 cfm ✓

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	P_m Orifice ΔH "H_2O Desired	Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
1-4	1803	594.533	1.20	0.67	0.67	4.5	325	280	262	58	97	97	Pb = 29.66
3	1809	596.72	1.40	0.78	0.78	5.0	327	274	269	55	97	96	Ps = -14.1
2	1811	598.86	1.30	0.72	0.72	5.0	326	274	270	56	97	96	
1	1815	600.91	1.10	0.61	0.61	4.0	327	275	268	54	97	96	
End	1819	603.146	–	–	–	–	–	–	–	–	–	–	vol = 0.501 ✓
2-4	1820	603.647	1.10	0.61	0.61	4.0	327	273	277	53	98	97	
3	1824	605.71	1.00	0.56	0.56	4.0	326	277	279	55	99	97	
2	1828	607.68	1.00	0.56	0.56	4.0	325	275	280	54	100	97	
1	1832	609.32	0.95	0.53	0.53	4.0	329	276	284	56	100	97	
End	1836	611.053	–	–	–	–	–	–	–	–	–	–	vol = 0.489 ✓
3-4	1837	611.542	1.00	0.56	0.56	4.0	324	273	280	56	100	98	
3	1841	613.31	1.10	0.61	0.61	4.0	328	271	280	58	100	98	
2	1845	615.37	1.10	0.61	0.61	4.0	329	277	279	58	100	98	
1	1849	617.41	1.10	0.61	0.61	4.0	328	274	280	59	100	98	
End	1853	619.173	–	–	–	–	–	–	–	–	–	–	vol = 0.529 ✓
4-4	1854	619.702	1.10	0.61	0.61	5.0	329	274	279	59	100	98	
3	1858	621.53	1.20	0.67	0.67	5.0	329	277	283	59	100	98	
2	1902	623.47	1.20	0.67	0.67	5.0	332	289	282	59	100	98	

Pitot Tube Calibration Factor C_p 0.806 ✓ low side
Volume Collected V_m ~~58.396~~ ft^3 58.628 ✓
Water Collected V_w 149.7 ✓ ml
Time of Test T_t 128 ✓ min. ✓
Stack Pressure P_s ~~29.66~~ -14.1 "H_2O

Pitot Tube No. 53-5-1 ✓
Baro. Press. P_b 29.66 ✓ "Hg
Probe Tip Dia. D_n 0.190 ✓ in.
% CO_2 14.6 ✓ % CO 0.0 ✓
% O_2 5.8 ✓ % N_2 79.6 ✓
Area Stack A_s ~~21,024~~ ✓ in^2 16,279

Barometer No. 53-3 ✓ Probe Tip No. 05-233-7 ✓
Total Volume of Leak Checks After Start: ~~3.614~~ ft^3 3.387 ✓
V_m = Dry Gas Meter Calibration Factor ~~58.572~~ X 0.992 ✓
58.804 ✓
{Dry Gas Meter Reading – ft^3 – (T_t – min. X Leak Rate – cfm)}

VERSION 1
22 OCTOBER 2002

Impinger Box No. S1-1

Water Weight Gain

Impinger 1	Final Weight	863.5	Impinger 1	125.5
	Initial Weight	738.0	Impinger 2	15.9
	Increase	125.5		
Impinger 2	Final Weight	730.4	Impinger 3	3.3
	Initial Weight	714.5	Impinger 4	2.3
	Increase	15.9		
Impinger 3	Final Weight	657.5	Impinger 5	0.0
	Initial Weight	654.2	Impinger 6	2.7
	Increase	3.3		
Impinger 4	Final Weight	739.9	Impinger 7	
	Initial Weight	737.6	Total	149.7 ✓ = V_w
	Increase	2.3		
Impinger 5	Final Weight	732.5		
	Initial Weight	732.5		
	Increase	0.0		
Impinger 6	Final Weight	920.3		
	Initial Weight	917.6		
	Increase	2.7		
Impinger 7	Final Weight			
	Initial Weight			
	Increase			

V_w =
g SO_2 = -
V_w =

P_b = 29.66 ✓		%CO_2 = 14.6 ✓	
V_m = ~~58.396~~ 58.628		%O_2 = 5.8 ✓	
V_w = 149.7 ✓		%CO = 0.0 ✓	
P_m = 0.553 ✓		%N_2 = 79.6 ✓	
Avg ΔP = 0.977 ✓		A_s = ~~21.6221~~ 21.6219 ✓	
		D_n = 0.190 ✓	
Avg$\sqrt{\Delta P}$ = 0.976 ✓		T_t = 128 ✓	
C_p = 0.806 ✓			
P_s = -14.1 ✓ "H_2O		28.62 "Hg	
T_m = 98 ✓ °F		558 ✓ °R	
T_s = 331 ✓ °F		791 ✓ °R	

Moisture Content: %M = ~~11.41~~ 11.37 ✓ M_d = ~~0.8859~~ 0.8863 ✓ MW_d = 30.568 ✓ MW = ~~29.13~~ 29.14 ✓

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times \cancel{58.396}\ 58.628 \left[\frac{29.66 + \frac{0.553}{13.6}}{98 + 460}\right] = \frac{\cancel{54.860}\ 55.078 \text{ sft}^3}{\cancel{0.429}\ 0.430 \text{ scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x 149.7 ✓ = 7.066 ✓ sft^3

% Moisture = $\frac{Vw_{gas}}{Vm_{std} + Vw_{gas}}$ x 100 = $\frac{7.066}{55.078\ \cancel{54.860} + 7.066}$ x 100 = ~~11.41~~ 11.37 ✓ %

V_s = 5123.8 x 0.806 ✓ $\sqrt{\frac{791}{28.62 \times \cancel{29.13}\ 29.14}}$ x 0.976 ✓ = ~~3926~~ 3925 ✓ fpm

%I = $\frac{1{,}039 \times \cancel{54.860}\ 55.078 \times 791}{128 \times 28.62 \times \cancel{0.8859}\ 0.8863 \times \cancel{3926}\ 3925 \times (0.190)^2}$ = ~~98.0~~ 98.4 %

ACFM: ~~573209~~ 443763 ✓

SCFM: ~~325423~~ 252,027 ✓

%EA: 37.9 ✓

Run Number 2 M17/26A FIELD DATA

Unit Esp Inlet Exhaust Duct

Date 8-17-05

Point	Clock Time	Dry Gas Meter, CF	ΔPs "Pitot" "H_2O	Orifice ΔH "H_2O Desired	Pm Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	Ts Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	Tm Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
4-1	1906	625.498	1.00	0.56	0.56	4.0	332	276	279	60	100	99	
End	1910	627.493	—	—	—	—	—	—	—	—	—	—	vol = 0.351 ✓
8-4	1930	627.844	0.63	0.37	0.37	3.0	326	282	280	67	101	99	Δ Factor fs = 0.583
3	1934	629.52	0.45	0.26	0.26	3.0	330	283	281	66	98	98	
2	1938	630.90	0.26	0.12	0.12	2.0	340	286	281	66	98	98	
1	1942	631.82	0.31	0.18	0.18	2.0	339	287	280	63	97	98	
End	1946	632.903	—	—	—	—	—	—	—	—	—	—	vol = 0.518 ✓
10-4	2002	633.421	1.10	0.64	0.64	4.0	330	291	283	51	98	97	
3	2006	635.17	1.00	0.58	0.58	3.0	328	279	282	52	97	97	
2	2010	637.27	0.90	0.52	0.52	3.0	331	279	283	52	97	97	
1	2014	639.00	0.61	0.34	0.36	3.0	322	281	280	52	98	97	
End	2018	640.617	—	—	—	—	—	—	—	—	—	—	vol = 0.419 ✓
11-4	2019	641.036	0.90	0.52	0.52	4.0	334	266	278	53	98	97	
3	2023	642.773	0.94	0.55	0.55	4.0	333	258	282	54	99	97	
2	2027	644.52	0.90	0.52	0.52	4.0	336	261	283	55	99	97	
1	2031	646.38	0.80	0.47	0.47	4.0	338	268	280	54	99	97	
End	2035	648.007	—	—	—	—	—	—	—	—	—	—	vol = 0.580 ✓
12-4	2036	648.587	1.10	0.64	0.64	6.0	341	268	282	55	100	97	
3	2040	650.70	1.10	0.64	0.64	6.0	341	270	280	55	100	97	
2	2044	652.37	1.20	0.70	0.70	6.0	340	270	280	55	102	97	
1	2048	654.12	1.20	0.70	0.70	6.0	342	270	281	55	102	97	
End	2052	656.724	—	—	—	—	—	—	—	—	—	—	

Version 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

17124A **Field Data**

Job Number 05-233-TASK 1
Job Name ADA-ES
Run Number 3
Unit Esp Inlet Duct
Date 8-18-05
Operator Simpson, Ware, Bornsen
Sample box No. 51-1 Meter Box No. 53-1

Read and record at the start of each test point.

Purge to: —
Purge time: —
Pitot Leak Check Initial ✓ Final ✓

Ambient Temp. °F 90°
Assumed Moisture % 12%
Probe Length 10'
C Factor 0.583 to reference.
Initial Leak @ 15.0 "Hg = 0.000 cfm
Final Leak @ 8.0 "Hg = 0.000 cfm

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	P_m Orifice ΔH "H_2O Desired	Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
12-4	1100	673.294	1.20	0.70	0.70	4.5	~~308~~ 328	258	269	61	92	92	Pb = 29.67
3	1104	675.38	1.20	0.70	0.70	4.5	340	259	273	55	93	92	Ps = -14.5
2	1108	677.40	1.30	0.76	0.76	5.0	333	257	271	55	95	92	
1	1112	679.47	1.30	0.76	0.76	5.0	324	262	277	54	96	92	
End	1116	681.574	—	—	—	—	—	—	—	—	—	—	vol = 0.857
11-4	1118	682.431	1.20	0.70	0.70	5.0	320	263	278	54	97	93	
3	1122	684.49	1.10	0.64	0.64	5.0	339	260	279	54	98	93	
2	1126	686.38	1.10	0.64	0.64	5.0	333	261	280	54	98	93	
1	1130	688.21	0.85	0.50	0.50	4.0	329	268	281	54	100	93	
End	1134	690.021	—	—	—	—	—	—	—	—	—	—	vol = 0.725
16-4	1136	690.746	1.20	0.70	0.70	5.0	330	256	278	54	100	94	
3	1140	692.71	1.20	0.70	0.70	5.0	340	257	277	54	100	95	
2	1144	694.73	0.85	0.50	0.50	4.0	325	261	274	55	101	95	
1	1148	696.65	0.85	0.50	0.50	4.0	320	263	273	56	102	96	Leak @ 8.0 = 0.000
End	1152	698.333	—	—	—	—	—	—	—	—	—	—	vol = 1.463
8-4	1209	699.796	0.80	0.47	0.47	4.0	318	251	257	62	100	98	
3	1213	701.49	0.69	0.40	0.40	4.0	334	241	274	60	100	98	
2	1217	703.60	0.50	0.29	0.29	3.0	323	258	287	62	100	98	

Pitot Tube Calibration Factor C_p 0.808
Volume Collected V_m ~~62.268~~ ft³ 61.779
Water Collected V_w 164.4 ml
Time of Test T_t 128 min.
Stack Pressure P_s -14.5 "H_2O

Pitot Tube No. 54-12-1
Baro. Press. P_b 29.67 "Hg
Probe Tip Dia. D_n 0.190 in.
% CO_2 14.0 % CO 0.0
% O_2 4.8 % N_2 81.2
Area Stack A_s ~~21,024~~ in² 16279

Barometer No. 53-3 Probe Tip No. 5-233-7
Total Volume of Leak Checks After Start: — ft³ 5.895
V_m = Dry Gas Meter Calibration Factor ~~62.455~~ x 0.997 61.965
{Dry Gas Meter Reading — ft³ – (T_t — min. X Leak Rate — cfm)}

VERSION 1
22 OCTOBER 2002

Inlet

Impinger Box No. 51-1

				Water Weight Gain	
Impinger 1	Final Weight	880.4		Impinger 1	137.1
	Initial Weight	743.5			
	Increase	137.1		Impinger 2	17.4
Impinger 2	Final Weight	734.0			
	Initial Weight	716.6		Impinger 3	2.0
	Increase	17.4		Impinger 4	1.6
Impinger 3	Final Weight	655.2	V_w =		
	Initial Weight	653.2	g SO_2 = - —	Impinger 5	1.4
	Increase	2.0	V_w =	Impinger 6	4.9
Impinger 4	Final Weight	740.2		Impinger 7	
	Initial Weight	738.6			
	Increase	1.6		Total	164.4 ✓ = V_w
Impinger 5	Final Weight	737.4			
	Initial Weight	736.0			
	Increase	1.4			
Impinger 6	Final Weight	925.0			
	Initial Weight	920.1			
	Increase	4.9			
Impinger 7	Final Weight				
	Initial Weight				
	Increase				

P_b = 29.67 ✓ %CO_2 = 14.0 ✓
V_m = ~~62.2268~~ 61.779 ✓ %O_2 = 4.8 ✓
V_w = 164.4 ✓ %CO = ~~0~~.0 ✓
P_m = ~~0.600~~ 0.620 ✓ %N_2 = 81.2 ✓
Avg ΔP = 1.063 ✓ A_s = ~~21.024~~ 16.279 ✓
D_n = 0.190 ✓
Avg$\sqrt{\Delta P}$ = 1.023 ✓ T_t = 128 ✓
C_p = 0.808 ✓
P_s = -14.5 ✓ "H_2O 28.60 ✓ "Hg
T_m = ~~98~~ 99 °F ~~558~~ 559 ✓ °R
T_s = 323 ✓ °F 783 ✓ °R

Moisture Content: %M = ~~11.71~~ 11.81 ✓ M_d = ~~0.8829~~ 0.8819 ✓ MW_d = 30.432 ✓ MW = ~~28.98~~ 28.96 ✓

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times \cancel{62.268}\ 61.779 \left[\frac{29.67 + \frac{\cancel{0.600}\ 0.620}{13.6}}{\cancel{98}\ 99 + 460}\right] = \frac{\cancel{58.525}\ 57.964\ \text{sft}^3}{\cancel{0.457}\ 0.453\ \text{scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x 164.4 ✓ = 7.760 ✓ sft^3

% Moisture = $\frac{Vw_{gas}}{Vm_{std} + Vw_{gas}}$ x 100 = $\frac{7.760}{57.964\ \cancel{58.525} + 7.760}$ x 100 = ~~11.71~~ 11.81 ✓ %

V_s = 5123.8 x 0.808 ✓ $\sqrt{\frac{783}{28.60 \times \cancel{28.98}\ 28.96}}$ x 1.023 ✓ = ~~416~~ 4118 ✓ fpm

ACFM: ~~601,008~~ 465,525 ✓

SCFM: ~~343,257~~ 265,609 ✓

%I = $\frac{1{,}039 \times 783 \times \cancel{58.525}\ 57.964}{\cancel{416}\ 4118 \times \cancel{0.8829}\ 0.8819 \times 28.60 \times 128 \times (0.190)^2}$ = ~~99.1~~ 98.2 ✓ %

%EA: 28.7%

Run Number 3
Unit ESP Inlet Duct
Date 8-18-05

17/26A FIELD DATA

			ΔP_s		P_m		T_s				T_m		
Point	Clock Time	Dry Gas Meter, CF	"Pitot" "H_2O	Orifice ΔH "H_2O Desired	Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
8-1	1221	704.33	0.47	0.28	0.28	3.0	308	260	280	64	101	99	
End	1225	705.651	—	—	—	—	—	—	—	—	—	—	vol = 0.493
4-4	1237	706.144	1.00	0.58	0.58	5.0	318	254	289	67	100	99	Pb = 29.67
3	1241	708.02	1.30	0.76	0.76	6.0	327	254	285	56	102	100	Ps = -14.5
2	1245	709.98	1.30	0.76	0.76	6.0	315	259	285	51	102	100	
1	1249	712.27	1.10	0.64	0.64	5.0	307	261	282	52	102	101	
End	1253	714.764	—	—	—	—	—	—	—	—	—	—	vol = 0.734
3-4	1255	714.998	1.00	0.58	0.58	5.0	310	254	280	47	103	101	
3	1259	716.83	1.10	0.64	0.64	6.0	330	255	279	47	104	100	
2	1303	718.80	1.10	0.64	0.64	6.0	324	255	276	47	104	101	
1	1307	720.81	0.70	0.41	0.41	5.0	326	257	279	47	103	101	
End	1311	722.476	—	—	—	—	—	—	—	—	—	—	vol = 0.772
2-4	1313	723.248	0.80	0.47	0.47	5.0	314	256	279	47	104	101	
3	1317	725.12	1.10	0.64	0.64	5.0	315	256	277	47	104	101	
2	1321	726.998	1.10	0.64	0.64	5.0	316	258	277	48	105	102	
1	1325	728.96	1.20	0.70	0.70	5.0	310	251	279	47	105	102	
End	1329	730.834	—	—	—	—	—	—	—	—	—	—	vol = 0.851
1-4	1331	731.687	1.30	0.74	0.74	6.0	317	252	277	48	106	102	
3	1335	733.95	1.50	0.87	0.87	6.0	324	255	277	48	106	102	
2	1339	736.18	1.50	0.87	0.87	6.0	322	256	278	48	106	102	
1	1343	738.32	1.10	0.64	0.64	6.0	311	258	274	49	106	102	
End	1348	741.154	—	—	—	—	—	—	—	—	—	—	

Version 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

Job Number 05-233 task 1 ✓

Job Name ADA - ES ✓

Run Number 1 ✓

Unit Unit 2 ESP Inlet ✓

Date 8/17/05 ✓

Operator Malone | Orr | Bornsen

Sample box No. 51-1 Meter Box No. 28-3 ✓

O-HYDRO ~~Meth 17~~ Field Data

Read and record at the start of each test point.

Purge to: –

Purge time: –

Pitot Leak Check Initial ✓ Final ✓ ✓

Ambient Temp. °F 85

Assumed Moisture % 12

Probe Length 5'

C Factor ~~0.489~~ 0.812 to reference.

Initial Leak @ 15.0 "Hg = 0.001 cfm ✓

Final Leak @ 7.0 "Hg = 0.007 cfm ✓

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	P_m Orifice ΔH "H_2O Desired	Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
1-4	1110	116.969	1.20	0.59	0.59	3.0	305	267	271	80	80	78	Pb: 29.78
3	1114	119.00	1.20	0.59	0.59	3.0	310	272	271	67	80	78	Ps: -14.1
2	1118	120.70	1.20	0.59	0.59	3.0	311	262	270	66	81	79	
1	1122	122.40	1.20	0.59	0.59	3.0	311	260	272	65	81	79	
END	1126	123.805	–	–	–	–	–	–	–	–	–	–	vol: 0.442 ✓
2-4	1127	124.297	1.10	0.53	0.53	3.0	310	257	268	67	82	79	
3	1131	125.956	1.00	0.49	0.49	3.0	312	252	266	67	82	79	
2	1135	127.46	0.97	0.47	0.47	3.0	312	256	264	66	82	80	
1	1139	128.87	0.92	0.45	0.45	3.0	307	268	266	68	83	80	
END	1143	130.431	–	–	–	–	–	–	–	–	–	–	
3-4	1230	130.431	1.00	0.49	0.49	3.0	305	262	257	65	80	80	
3	1234	132.00	1.00	0.49	0.49	3.0	312	271	258	66	80	80	
2	1238	133.86	1.00	0.49	0.49	3.0	312	263	259	66	81	80	
1	1242	135.07	0.68	0.33	0.33	3.0	293	267	264	66	81	80	
END	1246	136.295	–	–	–	–	–	–	–	–	–	–	
4-4	1247	136.681	1.20	0.59	0.59	3.0	313	263	259	67	82	80	Vol. 0.386
3	1251	138.40	1.30	0.64	0.64	3.0	318	258	257	68	83	81	Ps: -14.0
2	1255	140.20	1.30	0.64	0.64	3.0	322	264	260	68	83	81	Pb: 29.75

Pitot Tube Calibration Factor C_p 0.814 ✓ low side

Volume Collected V_m ~~58.135~~ ft³ 57.746

Water Collected V_w ~~166.2~~ 167.2 ml

Time of Test T_t 128 ✓ min.

Stack Pressure P_s -14.1 ✓ "H_2O

Pitot Tube No. 54-S-1 ✓

Baro. Press. P_b 29.77 ✓ "Hg

Probe Tip Dia. D_n 0.193 ✓ in.

% CO_2 14.8 ✓ % CO 0.0 ✓

% O_2 5.4 ✓ % N_2 79.8 ✓

Area Stack A_s ~~21024~~ 16279 in²

Barometer No. 53-3 ✓ Probe Tip No. 05-233-4 ✓

Total Volume of Leak Checks After Start: ~~1.036~~ ft³ 1.422

V_m = Dry Gas Meter Calibration Factor 1.008 ✓ X ~~57.674~~ 57.288 ✓

{Dry Gas Meter Reading – ft³ – (T_t – min. X Leak Rate – cfm)}

VERSION 1
22 OCTOBER 2002

Impinger Box No. 51-1

Water Weight Gain

Impinger 1	Final Weight	853.5
	Initial Weight	724.3
	Increase	129.2
Impinger 2	Final Weight	743.0
	Initial Weight	725.1
	Increase	17.9
Impinger 3	Final Weight	654.3
	Initial Weight	652.4
	Increase	1.9
Impinger 4	Final Weight	733.0
	Initial Weight	732.0
	Increase	1.0
Impinger 5	Final Weight	738.0
	Initial Weight	736.8
	Increase	1.2
Impinger 6	Final Weight	716.0
	Initial Weight	716.2
	Increase	-0.2
Impinger 7	Final Weight	648.2
	Initial Weight	648.0
	Increase	0.2

V_w =
g SO_2 = -
V_w =

993.0 F
Imp. 8 977.0 I
16.0

Impinger 1	129.2
Impinger 2	17.9
Impinger 3	1.9
Impinger 4	1.0
Impinger 5	1.2
Impinger 6	-0.2
Impinger 7	0.2
Imp. 8	16.0
Total	~~166.2~~ 167.2 = V_w

P_b =	29.77		%CO_2 =	14.8	
V_m =	~~58.135~~ 57.746		%O_2 =	5.4	
V_w =	~~166.2~~ 167.2		%CO =	0.0	
P_m =	0.642		%N_2 =	79.8	
Avg ΔP =	0.983		A_s =	~~21.024~~ 16.279	
			D_n =	0.193	
Avg$\sqrt{\Delta P}$ =	0.982		T_t =	128	
C_p =	0.816				
P_s =	-14.1	"H_2O		28.73	"Hg
T_m =	83	°F		543	°R
T_s =	320	°F		780	°R

Moisture Content: %M = ~~12.22~~ 12.36 M_d = ~~0.8778~~ 0.8764 MW_d = 30.584 MW = ~~29.05~~ 29.03

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times \cancel{58.135}\ 57.746 \left[\frac{29.77 + \frac{0.642}{13.6}}{83 + 460}\right] = \frac{\cancel{56.292}\ 55.967 \text{ sft}^3}{\cancel{0.440}\ 0.431 \text{ scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x ~~166.2~~ 167.2 = ~~7.845~~ 7.892 sft³

% Moisture = $\frac{Vw_{gas}}{Vm_{std} + Vw_{gas}}$ x 100 = $\frac{\cancel{7.845}\ 7.892}{\cancel{56.292}\ 57.746 + \cancel{7.845}\ 7.892}$ x 100 = ~~12.22~~ 12.36 %

V_s = 5123.8 x 0.816 $\sqrt{\frac{780}{28.73 \times \cancel{29.05}\ 29.03}}$ x 0.982 = ~~3969~~ 3971 fpm

%I = $\frac{1{,}039 \times 780 \times \cancel{56.292}\ 55.967}{128 \times 28.73 \times \cancel{0.8778}\ 0.8764 \times \cancel{3969}\ 3971 \times (0.193)^2}$ = ~~95.6~~ 95.1 %

ACFM: ~~579,500~~ 448,864

SCFM: ~~331,847~~ 256,677

%EA: 34.3

Run Number 1 ✓
Unit Unit 2 ESP Inlet ✓
Date 8/17/05 ✓

D-HYDRO FIELD DATA

Point	Clock Time	Dry Gas Meter, CF	ΔPs "Pitot" "H₂O	Orifice ΔH "H₂O Desired	Pm Orifice ΔH "H₂O Actual	Pump Vacuum "Hg Gauge	Ts Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	Tm Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
4-1	1259	141.85	1.10	0.53	0.53	3.0	323	265	261	68	83	81	
END	1303	143.567	–	–	–	–	–	–	–	–	–	–	leak ✓ 6.0 good @ 0.004
8-4	1324	143.786	0.60	0.52	0.52	3.0	333	264	259	67	83	82	vol: 0.219 ✓
3	1328	144.70	0.60	0.52	0.52	3.0	333	264	262	65	83	82	*cf : 0.857
2	1332	146.80	0.30	0.26	0.26	3.0	333	266	262	66	84	82	
1	1336	148.00	0.45	0.39	0.39	3.0	327	267	261	67	85	82	*
END	1340	149.680	–	–	–	–	–	–	–	–	–	–	vol: 0.325 ✓
10-4	1341	150.005	1.00	0.86	0.86	3.5	330	268	266	68	86	82	
3	1345	152.20	0.92	0.79	0.79	3.5	332	269	262	67	86	82	
2	1349	153.90	~~0.90~~ 0.93 ~~0.75~~ @	~~0.69~~ 0.80	0.80	3.5	331	267	261	67	86	83	ΔP: 0.93 ΔH: 0.80
1	1353	155.80	0.70	0.60	0.60	3.5	320	270	263	68	87	83	
END	1357	157.809	–	–	–	–	–	–	–	–	–	–	
11-4	1444	157.809	1.00	0.86	0.86	3.5	321	253	259	70	86	85	
3	1448	160.10	1.00	0.86	0.86	3.5	330	263	260	66	87	85	
2	1452	162.23	0.97	0.83	0.83	3.5	331	266	260	67	87	85	
1	1456	164.50	0.92	0.79	0.79	3.5	330	272	261	65	88	86	
END	1500	166.305	–	–	–	–	–	–	–	–	–	–	
12-4	1511	166.305	1.00	0.86	0.86	3.5	326	260	258	64	88	86	
3	1515	168.60	1.10	0.90	0.90	3.5	333	270	259	66	88	86	
2	1519	170.60	1.30	1.12	1.10	3.5	334	272	260	64	90	86	
1	1523	172.95	1.30	1.12	1.10	3.5	334	271	261	65	90	86	
END	1527	175.679	–	–	–	–	–	–	–	–	–	–	

Version 1

METCO ENVIRONMENTAL

Job Number 05-233 task 1 ✓
Job Name ADA - ES ✓
Run Number 2 ✓
Unit Unit 2 ESP Inlet ✓
Date 8/17/05 ✓
Operator Malone/Orr/Bomser
Sample box No. 51-3 Meter Box No. 28-3 ✓

O-HYDRO ~~Meth 17~~ Field Data

Read and record at the start of each test point.

Purge to: —
Purge time: —
Pitot Leak Check Initial ✓ Final ✓ ✓

Ambient Temp. °F 95
Assumed Moisture % 12
Probe Length 5'
C Factor 0.812 to reference.
Initial Leak @ 16.0 "Hg = 0.002 cfm ✓
Final Leak @ 23.0 "Hg = 0.000 cfm ✓

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	P_m Orifice ΔH "H_2O Desired	Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
12-4	1816	176.878	1.10	0.89	0.89	4.0	330	251	272	80	90	90	Pb: 29.66
3	1820	179.20	1.10	0.89	0.89	4.0	336	261	269	67	91	90	Ps: -14.1
2	1824	181.75	1.30	1.06	1.10	4.0	337	258	274	67	91	90	
1	1828	184.05	1.10	0.89	0.89	4.0	333	261	270	66	92	91	
END	1832	185.859	—	—	—	—	—	—	—	—	—	—	vol: 0.631 ✓
11-4	1833	186.490	1.10	0.89	0.89	4.0	329	273	271	66	92	90	
3	1837	188.21	1.10	0.89	0.89	4.0	334	259	273	65	92	90	
2	1841	190.70	0.98	0.80	0.80	4.0	333	255	270	65	92	90	
1	1845	192.63	0.86	0.70	0.70	4.0	326	261	270	65	91	90	
END	1849	194.460	—	—	—	—	—	—	—	—	—	—	vol: 0.590 ✓
10-4	1850	195.050	1.00	0.81	0.81	4.0	330	256	268	68	91	90	
3	1854	197.40	0.86	0.70	0.70	4.0	328	262	272	67	91	90	
2	1858	198.90	0.86	0.70	0.70	4.0	328	263	271	67	91	90	
1	1902	200.57	0.55	0.45	0.45	3.5	317	270	273	67	91	90	
END	1906	202.105	—	—	—	—	—	—	—	—	—	—	vol: 0.553 ✓
8-4	1907	202.658	0.40	0.32	0.32	3.0	326	256	262	68	91	90	
3	1911	203.80	0.48	0.39	0.39	3.5	331	249	256	66	91	90	
2	1915	205.30	0.48	0.39	0.39	3.5	330	256	255	67	91	90	

Pitot Tube Calibration Factor C_p 0.816 ✓ (low 3.20)
Volume Collected V_m ~~61.773~~ ft^3 61.043
Water Collected V_w 173.9 ✓ ml
Time of Test T_t 128 ✓ min.
Stack Pressure P_s -14.1 ✓ "H_2O

Pitot Tube No. 54-5-1 ✓
Baro. Press. P_b 29.66 ✓ "Hg
Probe Tip Dia. D_n ~~0.1930~~ 0.190 ✓ in.
% CO_2 14.6 ✓ % CO 0.0 ✓
% O_2 5.8 ✓ % N_2 79.6 ✓
Area Stack A_s ~~21,027~~ ✓ in^2 16,279

Barometer No. 53-3 ✓ Probe Tip No. 05-233-5
Total Volume of Leak Checks After Start: ~~2.077~~ ft^3 ~~2.312~~ 3.036
V_m = Dry Gas Meter Calibration Factor 1.008 ✓ X ~~61.283~~ 60.559 ✓

{Dry Gas Meter Reading — ft^3 – (T_t — min. X Leak Rate — cfm)}

VERSION 1
22 OCTOBER 2002

Impinger Box No. 51-3

			Water Weight Gain	
Impinger 1	Final Weight	873.2	Impinger 1	132.1
	Initial Weight	741.1		
	Increase		Impinger 2	19.0
Impinger 2	Final Weight	754.1	Impinger 3	3.6
	Initial Weight	735.1		
	Increase		Impinger 4	2.2
Impinger 3	Final Weight	745.2	Impinger 5	0.0
	Initial Weight	741.6		
	Increase		Impinger 6	-0.7
Impinger 4	Final Weight	629.4	Impinger 7	0.3
	Initial Weight	627.2	Imp 8	17.4
	Increase		Total	173.9 = V_w
Impinger 5	Final Weight	746.8		
	Initial Weight	746.8		
	Increase			
Impinger 6	Final Weight	733.1		
	Initial Weight	733.8		
	Increase			
Impinger 7	Final Weight	748.3		
	Initial Weight	748.0		
	Increase			

V_w =

g SO_2 = -

V_w =

Imp 8 F 955.6 I 973.0

P_b = 29.66		$\%CO_2$ =	14.6
V_m = ~~61.773~~ 61.043		$\%O_2$ =	5.8
V_w = 173.9		%CO =	0.0
P_m = 0.785		$\%N_2$ =	79.6
Avg ΔP = 0.966		A_s =	~~21024~~ 16,279
		D_n =	~~21024~~ 0.190
Avg$\sqrt{\Delta P}$ = 0.972		T_t =	128
C_p = 0.816			
P_s = -14.1 "H_2O		28.62 "Hg	
T_m = 91 °F		551 °R	
T_s = 321 °F		781 °R	

Moisture Content: %M = ~~12.25~~ 12.38 M_d = ~~0.8775~~ 0.8762 MW_d = 30.568 MW = ~~29.03~~ 29.01

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times \cancel{61.773}\ 61.043 \left[\frac{29.66 + \frac{0.785}{13.6}}{91 + 460}\right] = \frac{\cancel{58.804}\ 58.109 \text{ sft}^3}{\cancel{0.459}\ 0.454 \text{ scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x 173.9 = 8.208 sft^3

% Moisture = $\frac{Vw_{gas}}{Vm_{std} + Vw_{gas}}$ x 100 = $\frac{8.208}{8.208 + \cancel{58.804}\ 58.109}$ x 100 = ~~12.25~~ 12.38 %

V_s = 5123.8 x 0.816 $\sqrt{\frac{781}{28.62 \times \cancel{29.03}\ 29.01}}$ x 0.972 = ~~3940~~ 3942 fpm

ACFM: ~~575,266~~ 445,585

SCFM: ~~327,629~~ 253,438

%I = $\frac{1{,}039 \times 781 \times \cancel{58.804}\ 58.109}{128 \times 28.62 \times \cancel{3940}\ 3942 \times \cancel{0.8775}\ 0.8762 \times (0.190)^2}$ = ~~104.4~~ 103.2 %

%EA: 37.9

VERSION 1
22 OCTOBER 2002

Run Number 2 ✓
Unit Unit 2 ESP Inlet ✓
Date 8/17/05 ✓

D-HYDRO Meth 17 FIELD DATA

			ΔP_s		P_m		T_s				T_m		
Point	Clock Time	Dry Gas Meter, CF	"Pitot" "H_2O	Orifice ΔH "H_2O Desired	Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
8-1	1919	206.30	0.30	0.24	0.24	3.0	326	264	256	68	91	90	
END	1923	207.577	–	–	–	–	–	–	–	–	–	–	Pb: 29.66
4-4	1955	207.577	1.20	0.97	0.97	5.0	311	272	263	68	89	90	Ps: -14.1
3	1959	209.78	1.20	0.97	0.97	6.0	313	260	268	67	89	90	
2	2003	211.87	1.20	0.97	0.97	6.0	313	253	268	64	90	90	
1	2007	213.80	1.10	0.89	0.89	6.5	303	258	266	64	90	90	
END	2011	215.650	–	–	–	–	–	–	–	–	–	–	vol. 0.462
3-4	2012	216.112	0.94	0.76	0.76	8.0	313	250	269	65	91	90	
3	2016	217.74	0.94	0.76	0.76	8.5	313	260	267	65	91	90	
2	2020	219.50	1.00	0.81	0.81	12.0	314	263	267	65	92	90	
1	2024	221.35	0.94	0.76	0.76	14.0	311	267	267	65	92	90	
END	2028	223.201	–	–	–	–	–	–	–	–	–	–	vol. 262
2-4	2029	223.463	1.10	0.89	0.89	16.0	315	273	268	67	92	90	
3	2033	225.43	1.10	0.89	0.89	20.0	314	271	270	64	92	90	
2	2037	227.33	0.94	0.76	0.76	20.0	314	271	270	64	92	90	pump off @ 2040
1	2044	229.00	0.88	0.72	0.72	4.0	310	278	271	67	90	90	228.220
END	2048	231.312	–	–	–	–	–	–	–	–	–	–	pump on @ 2042
1-4	2049	231.580	1.30	1.06	1.10	4.0	311	264	272	68	92	93	228.490
3	2053	234.18	1.10	0.89	0.89	4.0	316	263	274	68	93	90	
2	2057	236.08	1.20	0.97	0.97	4.0	316	263	272	67	93	90	vol: 0.270 ✓
1	2101	238.30	1.20	0.97	0.97	4.0	305	261	271	66	93	90	vol: 0.268 ✓
END	2105	240.473	–	–	–	–	–	–	–	–	–	–	

Version 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

0-HYDRO ~~HM-TT~~ Field Data

Job Number 05-233 task 1 ✓
Job Name ADA-ES ✓
Run Number 3 ✓
Unit Unit 2 ESP Inlet ✓
Date 8/18/05 ✓
Operator Malone | Ware | Bornsen ✓
Sample box No. 51-3 Meter Box No. 28-3 ✓

Read and record at the start of each test point.

Purge to: –
Purge time: –
Pitot Leak Check Initial ✓ Final ✓ ✓

Ambient Temp. °F 90
Assumed Moisture % 12
Probe Length 5'
C Factor 0.772 to reference.
Initial Leak @ 16.0 "Hg = 0.000 cfm ✓
Final Leak @ 14.0 "Hg = 0.000 cfm ✓

Point	Clock Time	Dry Gas Meter, CF	ΔPs "Pitot" "H_2O	Pm Orifice ΔH "H_2O Desired	Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	Ts Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	Tm Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
1-4	1110	241.213	1.20	0.93	0.93	4.0	315	274	273	80	88	87	Pb: 29.67
3	1114	243.40	1.40	1.08	1.10	4.0	316	263	271	67	89	87	Ps: -14.5
2	1118	245.70	1.20	0.93	0.93	4.0	314	264	274	65	90	87	
1	1122	248.00	1.20	0.93	0.93	4.0	302	262	265	65	91	87	
END	1126	249.781	–	–	–	–	–	–	–	–	–	–	vol: 0.490 ✓
2-4	1127	250.271	1.10	0.85	0.85	4.0	306	256	260	64	92	88	
3	1131	252.70	1.00	0.77	0.77	4.0	316	256	255	66	93	88	
2	1135	254.40	1.00	0.77	0.77	4.0	318	281	251	66	93	88	
1	1139	256.00	0.95	0.73	0.73	4.0	302	272	252	67	93	88	
END	1143	258.021	–	–	–	–	–	–	–	–	–	–	vol 0.466 ✓
3-4	1144	258.487	1.00	0.77	0.77	4.0	308	252	251	67	94	89	
3	1148	260.50	1.00	0.77	0.77	4.0	317	267	258	67	94	89	
2	1152	262.75	0.76	0.59	0.59	4.0	296	271	270	68	94	89	
1	1156	264.40	0.50	0.39	0.39	4.0	294	267	273	68	94	90	
END	1200	265.443	–	–	–	–	–	–	–	–	–	–	
4-4	1212	265.443	1.00	0.77	0.77	4.0	312	253	274	71	93	90	
3	1216	267.00	1.20	0.93	0.93	4.0	319	266	276	65	94	90	
2	1220	269.31	1.20	0.93	0.93	4.0	317	273	273	62	94	91	

Pitot Tube Calibration Factor C_p 0.816 ✓ low side
Volume Collected V_m 59.148 ✓ ft³
Water Collected V_w 172.0 ✓ ml
Time of Test T_t 128 ✓ min.
Stack Pressure P_s -14.5 ✓ "H_2O

Pitot Tube No. 54-5-1 ✓
Baro. Press. P_b 29.67 ✓ "Hg
Probe Tip Dia. D_n 0.190 ✓ in.
% CO_2 14.0 ✓ % CO 0.0 ✓
% O_2 4.8 ✓ % N_2 81.2 ✓
Area Stack A_s ~~21021~~ ✓ in²
16,279

Barometer No. 53-3 ✓ Probe Tip No. 05-233-45 ✓
Total Volume of Leak Checks After Start: 2.005 ✓ ft³
V_m = Dry Gas Meter Calibration Factor 1.008 ✓ x 58.679 ✓

{Dry Gas Meter Reading – ft³ – (T_t – min. X Leak Rate – cfm)}

VERSION 1
22 OCTOBER 2002

Impinger Box No. S1-3

			Water Weight Gain	
Impinger 1	Final Weight	858.9	Impinger 1	122.3
	Initial Weight	736.6		
	Increase		Impinger 2	22.0
Impinger 2	Final Weight	763.5	Impinger 3	3.9
	Initial Weight	741.5		
	Increase		Impinger 4	2.7
Impinger 3	Final Weight	745.6	Impinger 5	-0.1
	Initial Weight	741.7		
	Increase		Impinger 6	0.1
Impinger 4	Final Weight	633.3	Impinger 7	2.8
	Initial Weight	630.6	Imp 8	18.3
	Increase		Total	172.0 ✓ = V_w
Impinger 5	Final Weight	741.9		
	Initial Weight	742.0		
	Increase			
Impinger 6	Final Weight	738.1		
	Initial Weight	738.0		
	Increase			
Impinger 7	Final Weight	748.8		
	Initial Weight	746.0		
	Increase			

V_w =

g SO_2 = -

V_w =

Imp. 8 990.7
972.4

P_b =	29.67 ✓		%CO_2 =	14.0 ✓
V_m =	59.148 ✓		%O_2 =	4.8 ✓
V_w =	172.0 ✓		%CO =	0.0 ✓
P_m =	0.724 ✓		%N_2 =	81.2 ✓
Avg ΔP =	0.937 ✓		A_s =	~~21024~~ 16,279
			D_n =	0.190 ✓
Avg$\sqrt{\Delta P}$ =	0.953 ✓		T_t =	128 ✓
C_p =	0.816 ✓			
P_s =	-14.5 ✓ "H_2O		28.60 ✓	"Hg
T_m =	93 ✓ °F		553 ✓	°R
T_s =	319 ✓ °F		779 ✓	°R

Moisture Content: %M = 12.64 ✓ M_d = 0.8736 ✓ MW_d = 30.432 ✓ MW = 28.86 ✓

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times 59.148 \left[\frac{29.67 + \frac{0.724}{13.6}}{93 + 460}\right] = \frac{56.112 \text{ sft}^3}{0.438 \text{ scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x 172.0 ✓ = 8.118 ✓ sft³

$$\% \text{ Moisture} = \frac{Vw_{gas}}{Vm_{std} + Vw_{gas}} \times 100 = \frac{8.118}{56.112 + 8.118} \times 100 = 12.64\ \%$$

$$V_s = 5123.8 \times 0.816 \sqrt{\frac{779}{28.60 \times 28.86}} \times 0.953 = 3871 \text{ fpm}$$

ACFM: ~~565152~~ 437,601 ✓

SCFM: ~~321059~~ 248,598 ✓

$$\%I = \frac{1{,}039 \times 779 \times 56.112}{128 \times 28.60 \times 3871 \times 0.8736 \times (0.190)^2} = 101.6\ \%$$

%EA: 28.7 ✓

Run Number 3 ✓
Unit Unit 2 ESP Inlet ✓
Date 8/18/05 ✓

O-HYDRO / M17 FIELD DATA

			ΔP_s		P_m		T_s				T_m		
Point	Clock Time	Dry Gas Meter, CF	"Pitot" "H_2O	Orifice ΔH "H_2O Desired	Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
4-1	1224	271.20	1.10	0.85	0.85	7.0	305	282	273	62	95	91	vol: 0.287 ✓
END	1228	273.295	—	—	—	—	—	—	—	—	—	—	Pb: 29.67
8-4	1242	273.582	0.42	0.32	0.32	7.0	327	260	266	66	93	92	Ps: -14.5
3	1246	274.87	0.46	0.36	0.36	9.0	330	261	263	67	94	92	
2	1250	275.99	0.25	0.19	0.19	10.0	327	269	264	67	94	92	
1	1254	276.87	0.25	0.19	0.19	11.0	317	274	263	68	94	92	
END	1258	278.135	—	—	—	—	—	—	—	—	—	—	
10-4	1300	278.135	1.10	0.85	0.85	4.0	328	264	263	60	94	92	
3	1304	280.20	1.10	0.85	0.85	4.0	335	262	263	61	95	93	
2	1308	282.15	0.90	0.69	0.69	4.0	330	259	265	62	96	93	
1	1312	283.95	0.60	0.46	0.46	3.5	325	259	263	63	97	93	
END	1316	285.750	—	—	—	—	—	—	—	—	—	—	vol: 0.332 ✓
11-4	1317	286.082	1.00	0.77	0.77	4.0	329	267	267	65	97	93	
3	1321	288.15	1.00	0.77	0.77	4.0	334	267	266	66	98	94	
2	1325	290.05	0.95	0.73	0.73	4.0	332	261	266	62	98	94	
1	1329	292.50	0.95	0.73	0.73	4.0	322	268	268	67	98	94	
END	1333	293.750	—	—	—	—	—	—	—	—	—	—	vol: 0.430 ✓
12-4	1334	294.180	1.00	0.77	0.77	4.0	325	267	266	61	98	94	
3	1338	296.26	1.10	0.85	0.85	4.0	333	264	261	61	99	95	
2	1342	298.10	1.10	0.85	0.85	4.5	336	263	262	62	99	95	
1	1346	300.05	1.00	0.77	0.77	4.5	336	264	265	62	99	95	
END	1350	301.897	—	—	—	—	—	—	—	—	—	—	

Version 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

Job Number 05-233 ✓ | 17B/26A Field Data | Ambient Temp. °F 80

Job Name ADA ES ✓ | Assumed Moisture % 13

Run Number 1 TASK1 ✓ | Read and record at the start of each test point. | Probe Length ~~5~~ 7'

Unit ESP outlet Unit 2 ✓ | C Factor 10-75.3 to reference.

Date 8/17/05 ✓ | Purge to: – | Initial Leak @ 15.0 "Hg = 0.005 cfm ✓

Operator Goebel/Webber/Borensen | Purge time: – | Final Leak @ 10.0 "Hg = 0.005 cfm ✓

Sample box No. 51-3 Meter Box No. 28-2 ✓ | Pitot Leak Check Initial ✓ Final ✓ ✓

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	Orifice ΔH "H_2O Desired	P_m Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	port	Remarks
4	1101	623.351	0.75	1.40	1.40	3.0	286	271	258	59	83	81	1	
3	1105	626.17	0.59	1.10	1.10	3.0	290	264	266	54	84	80		
2	1109	628.09	0.54	1.00	1.00	3.0	286	253	263	53	85	80		
1	1113	630.31	0.21	0.39	0.39	2.5	200	254	268	53	87	80		
End	1117	632.619	–	–	–	–	–	–	–	–	–	–	–	
4	1118	632.619	0.82	1.55	1.55	4.5	301	267	258	56	89	81	2	Pb = 29.78
3	1122	634.21	0.81	1.55	1.55	4.5	305	268	257	53	91	81		Ps = -14.9"H_2O
2	1126	636.77	0.84	1.55	1.55	4.5	300	267	251	52	94	81		
1	1130	639.39	0.54	1.00	1.00	4.0	289	266	266	52	95	81		
End	1134	642.358	–	–	–	–	–	–	–	–	–	–		
4	1158	642.358	0.58	1.10	1.10	4.0	280	269	264	63	86	82	3	
3	1202	644.43	0.49	0.93	0.93	4.0	307	266	254	57	85	82		
2	1206	646.43	0.60	1.15	1.15	4.0	300	260	268	55	85	82		
1	1210	648.70	0.36	0.68	0.68	4.0	298	249	265	55	86	82		
End	1214	650.830	–	–	–	–	–	–	–	–	–	–		
4	1236	650.830	0.32	0.66	0.60	4.0	310	270	266	64	82	80	7	
3	1240	653.00	0.40	0.75	0.75	4.0	314	269	262	58	82	80	7	
2	1244	654.90	0.46	0.86	0.86	4.0	310	265	266	56	83	81		

Pitot Tube Calibration Factor C_p 0.797 ✓ lowside | Pitot Tube No. 53-5-2 ✓ | Barometer No. 53-3 ✓ Probe Tip No. 05-233-3 ✓

Volume Collected V_m 74.542 ✓ ft^3 | Baro. Press. P_b 29.77 ✓ "Hg | Total Volume of Leak Checks After Start: 1.957 ✓ ft^3

Water Collected V_w 203.7 ✓ ml | Probe Tip Dia. D_n 0.247 ✓ in. | V_m = Dry Gas Meter Calibration Factor 1.019 ✓ X 73.152 ✓

Time of Test T_t 128 ✓ min. | % CO_2 12.8 ✓ % CO 0.0 ✓

Stack Pressure P_s -14.8 ✓ "H_2O | % O_2 7.0 ✓ % N_2 80.2 ✓ | {Dry Gas Meter Reading ✓ ft^3 – (T_t – min. X Leak Rate – cfm)}

Area Stack A_s 21024 ✓ in^2

VERSION 1
22 OCTOBER 2002

Impinger Box No. 51.3

Impinger 1	Final Weight	827.7		
	Initial Weight	654.4		
	Increase			
Impinger 2	Final Weight	673.3		
	Initial Weight	653.3		
	Increase			
Impinger 3	Final Weight	646.7		
	Initial Weight	642.8		
	Increase			
Impinger 4	Final Weight	734.5		
	Initial Weight	734.4		
	Increase			
Impinger 5	Final Weight	716.2		
	Initial Weight	716.1		
	Increase			
Impinger 6	Final Weight	1004.7		
	Initial Weight	998.4		
	Increase			
Impinger 7	Final Weight			
	Initial Weight			
	Increase			

Water Weight Gain

Impinger 1	173.3
Impinger 2	20.0
Impinger 3	3.9
Impinger 4	0.1
Impinger 5	0.1
Impinger 6	6.3
Impinger 7	
Total	203.7 ✓ = V_w

V_w =
g SO_2 = -
V_w =

P_b =	29.77 ✓	%CO_2 =	12.8 ✓	
V_m =	74.542 ✓	%O_2 =	7.0 ✓	
V_w =	203.7 ✓	%CO =	0.0 ✓	
P_m =	1.095 ✓	%N_2 =	80.2 ✓	
Avg ΔP =	0.584 ✓	A_s =	21024 ✓	
		D_n =	0.247 ✓	
Avg$\sqrt{\Delta P}$ =	0.750 ✓	T_t =	128 ✓	
C_p =	0.797 ✓			
P_s =	-14.8 ✓ "H_2O		~~29.65~~ 28.68 ✓	"Hg
T_m =	89 ✓ °F		549 ✓	°R
T_s =	298 ✓ °F		758 ✓	°R

Moisture Content: %M = 11.85 ✓ M_d = 0.8815 ✓ MW_d = 30.328 ✓ MW = 28.87 ✓

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times 74.542 \checkmark \left[\frac{29.77 \checkmark + \frac{1.095 \checkmark}{13.6}}{89 \checkmark + 460}\right] = \frac{71.536 \checkmark \text{ sft}^3}{0.559 \checkmark \text{ scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x 203.7 ✓ = 9.615 ✓ sft³

% Moisture = $\frac{Vw_{gas}}{Vm_{std} + Vw_{gas}}$ x 100 = $\frac{9.615 \checkmark}{9.615 \checkmark + 71.536 \checkmark}$ x 100 = 11.85 ✓ %

V_s = 5123.8 x 0.797 ✓ $\sqrt{\frac{758 \checkmark}{\cancel{28.65}\ 28.68 \checkmark \times 28.87 \checkmark}}$ x 0.750 = ~~2932~~ 2,930 ✓ fpm

%I = $\frac{1{,}039 \times 71.536 \checkmark \times 758 \checkmark}{0.8815 \checkmark \times \cancel{28.65}\ 28.68 \checkmark \times \cancel{2932}\ 2930 \checkmark \times 128 \checkmark \times (0.247)^2}$ = 97.4 ✓ %

ACFM: ~~428069~~ 427,845 ✓

SCFM: ~~252,617~~ 253,709 ✓

%EA: 49.1 ✓

VERSION 1
22 OCTOBER 2002

Run Number 1 178/26A **FIELD DATA**

Unit ESP outlet Unit 2

Date 8/17/05

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	Orifice ΔH "H_2O Desired	P_m Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	port	Remarks
1	1248	656.82	0.15	0.28	0.28	3.0	260	255	257	55	85	81	7	
End	1252	658.693	—	—	—	—	—	—	—	—	—	—		
4	1407	660.650	0.56	1.05	1.05	3.5	281	270	260	63	87	85	10	lk @ 10.0
3	1411	662.94	0.57	1.10	1.10	3.5	321	266	262	55	91	85		0.005
2	1415	664.01	0.79	1.45	1.45	4.0	320	260	270	56	93	85		vol = 1.957
1	1419	667.52	0.60	1.18	1.10	4.0	280	266	265	54	95	85		Pb 28.75
End	1423	670.166	—	—	—	—	—	—	—	—	—	—		Ps -14.7
4	1424	670.166	0.58	1.10	1.10	4.0	316	265	262	58	97	86	10	
3	1428	672.12	0.60	1.10	1.10	4.0	322	267	255	56	98	86		
2	1432	674.31	0.80	1.50	1.50	4.0	328	263	263	55	100	86		
1	1436	676.80	0.67	1.25	1.25	4.0	386	261	262	53	102	87		
End	1440	679.42	—	—	—	—	—							
4	1441	679.42	0.90	1.70	1.70	4.5	308	256	261	55	103	88	11	
3	1445	682.01	0.86	1.60	1.60	4.5	328	252	263	53	105	88		
2	1449	685.97	0.83	1.55	1.55	4.5	323	254	266	53	105	88		
1	1453	687.54	0.38	0.72	0.72	3.5	300	261	262	53	105	89		
End	1457	689.553	—	—	—	—	—	—	—	—	—	—		
4	1458	689.553	0.77	1.45	1.45	4.0	306	273	252	56	104	89	12	
3	1502	692.29	0.79	1.50	1.50	4.5	326	265	256	53	106	89		
2	1506	694.88	0.26	0.49	0.49	3.5	308	265	270	51	107	90		
1	1510	696.62	0.26	0.49	0.49	3.5	288	266	268	52	105	90		
End	1514	698.460	—	—	—	—	—	—	—	—	—	—		

Version 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

Job Number 05-233 ✓
Job Name ADA ES ✓
Run Number 2 ✓
Unit ESP Outlet Unit 2 ✓
Date 8/17/05 ✓
Operator Goebel / Webber / Sorensen
Sample box No. 54-2 Meter Box No. 28-2 ✓

178/26A Field Data

Read and record at the start of each test point.

Purge to: —
Purge time: —
Pitot Leak Check Initial ✓ Final ✓ ✓

Ambient Temp. °F 88
Assumed Moisture % 13
Probe Length 7'
C Factor 10-75.3 to reference.
Initial Leak @ 15.5 "Hg = 0.005 cfm ✓
Final Leak @ 10.0 "Hg = 0.010 cfm ✓

1802

			ΔP_s	P_m			T_s		Line		T_m			
Point	Clock Time	Dry Gas Meter, CF	"Pitot" "H_2O	Orifice ΔH "H_2O Desired	Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	Stack Temp °F	Probe Temp °F	~~Oven~~ Temp °F	Effluent Temp °F	Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	port	Remarks
4	0602	699.385	0.55	1.05	1.05	4.5	331	252	250	63	94	94	12	run time
3	0606	701.31	0.72	1.35	1.35	5.0	342	250	251	56	95	95		1802-2048
2	0610	703.51	0.26	0.49	0.49	4.0	342	251	251	52	97	94		
1	0614	705.39	0.21	0.40	0.40	3.5	323	256	251	53	97	94		
End	0618	706.845	—	—	—	—	—	—	—	—	—	—		
4	0619	706.845	0.36	0.68	0.68	4.0	332	252	252	54	98	94	11	Pb = 29.66
3	0623	708.88	0.53	1.00	1.00	4.5	340	254	253	52	99	94		
2	0627	710.86	0.37	0.70	0.70	4.5	334	266	252	50	102	94		
1	0631	712.82	0.49	0.92	0.92	4.5	306	268	260	51	103	95		
End	0635	714.981	—	—	—	—	—	—	—	—	—	—		
4	0636	714.981	0.76	1.45	1.45	5.5	338	259	262	51	104	95	10	
3	0640	717.53	0.49	0.92	0.92	4.5	339	257	263	50	106	95		
2	0644	719.80	0.53	1.00	1.00	4.5	338	257	257	51	105	95		
1	0648	721.90	0.45	0.85	0.85	4.5	330	255	254	51	106	95		lk ✓ @ 11.0
End	0652	724.114	—	—	—	—	—	—	—	—	—	—		0.005
4	0701	725.240	0.35	0.66	0.66	4.5	331	258	251	62	102	95	7	vol 1.126 ✓
3	0705	727.18	0.41	0.77	0.77	4.5	333	250	260	59	102	95		
2	0709	729.10	0.40	0.76	0.76	4.5	327	248	258	59	103	95		

Pitot Tube Calibration Factor C_p 0.797 low side ✓
Volume Collected V_m 66.930 ✓ ft^3
Water Collected V_w 168.7 ✓ ml
Time of Test T_t 128 ✓ min.
Stack Pressure P_s -14.5 ✓ "H_2O

Pitot Tube No. 53-5-2 ✓
Baro. Press. P_b 29.66 ✓ "Hg
Probe Tip Dia. D_n ~~.25~~ 0.247 ✓ in.
% CO_2 13.6 ✓ % CO 0.0 ✓
% O_2 6.4 ✓ % N_2 80.0 ✓
Area Stack A_s 21024 ✓ in^2

Barometer No. 53-2 ✓ Probe Tip No. 05-233-3 ✓
Total Volume of Leak Checks After Start: 1.596 ✓ ft^3
V_m = Dry Gas Meter Calibration Factor 1.019 ✓ X 65.682 ✓

{Dry Gas Meter Reading — ft^3 – (T_t — min. X Leak Rate — cfm)}

VERSION 1
22 OCTOBER 2002

Impinger Box No. 54-2

			Water Weight Gain	
Impinger 1	Final Weight	879.5	Impinger 1	132.5
	Initial Weight	747.0		
	Increase	132.5	Impinger 2	15.8
Impinger 2	Final Weight	763.8	Impinger 3	3.5
	Initial Weight	748.0		
	Increase	15.8	Impinger 4	3.1
Impinger 3	Final Weight	548.9	Impinger 5	1.4
	Initial Weight	545.4		
	Increase	3.5	Impinger 6	12.4
Impinger 4	Final Weight	734.1	Impinger 7	
	Initial Weight	731.0		
	Increase	3.1	Total	168.7 ✓ = V_w
Impinger 5	Final Weight	746.8		
	Initial Weight	745.4		
	Increase	1.4		
Impinger 6	Final Weight	1000.5		
	Initial Weight	988.1		
	Increase	12.4		
Impinger 7	Final Weight			
	Initial Weight			
	Increase			

V_w =
g SO_2 = -
V_w =

P_b =	29.66 ✓		$\%CO_2$ =	13.6 ✓
V_m =	66.930 ✓		$\%O_2$ =	6.4 ✓
V_w =	168.7 ✓		%CO =	0.0 ✓
P_m =	~~0.467~~ 0.873 ✓		$\%N_2$ =	80.0 ✓
Avg ΔP =	0.463 ✓		A_s =	21024
			D_n =	0.247
Avg$\sqrt{\Delta P}$ =	0.669 ✓		T_t =	128
C_p =	0.797 ✓			
P_s =	-14.5 ✓	"H_2O	28.59 ✓	"Hg
T_m =	98 ✓	°F	558 ✓	°R
T_s =	324 ✓	°F	784 ✓	°R

Moisture Content: %M = ~~11.24~~ 11.23 ✓ M_d = ~~0.8876~~ 0.8877 ✓ MW_d = 30.432 ✓ MW = ~~29.03~~ 29.04 ✓

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times 66.930 ✓ \left[\frac{29.66 ✓ + \frac{\cancel{0.467}\ 0.873 ✓}{13.6}}{98 ✓ + 460}\right] = \frac{\cancel{62.864}\ 62.928\ \text{sft}^3}{\cancel{0.491}\ 0.492 ✓\ \text{scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x 168.7 ✓ = 7.963 ✓ sft^3

$$\%\ Moisture = \frac{Vw_{gas}}{Vm_{std} + Vw_{gas}} \times 100 = \frac{7.963 ✓}{62.928 ✓\ \cancel{62.864} + 7.963 ✓} \times 100 = \cancel{11.24}\ 11.23 ✓\ \%$$

$$V_s = 5123.8 \times 0.797 ✓ \sqrt{\frac{784 ✓}{\cancel{29.03}\ 29.04 ✓ \times 28.59 ✓}} \times 0.669 ✓ = 2655 ✓\ \text{fpm}$$

$$\%I = \frac{1{,}039 \times \cancel{62.864}\ 62.928 ✓ \times 784 ✓}{28.59 ✓ \times 2655 ✓ \times \cancel{0.8876}\ 0.8877 ✓ \times 128 \times (0.247)^2 ✓} = \cancel{97.3}\ 97.4 ✓\ \%$$

ACFM: ~~387665~~ 387,599 ✓

SCFM: ~~222229~~ 222,254 ✓

%EA: 43.2 ✓

Run Number 2

Unit ESP Outlet Unit 2

Date 8/17/05

5/26A FIELD DATA

Point	Clock Time	Dry Gas Meter, CF	ΔPs "Pitot" "H_2O	Orifice ΔH "H_2O Desired	Pm Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	Ts Stack Temp °F	Probe Temp °F	Line ~~Oven~~ Temp °F	Effluent Temp °F	Tm Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
1	0713	731.04	0.21	0.39	0.39	~~0.39~~ 4.0	298	252	256	56	104	95	7
End	0717	732.959	—	—	—	—	—	—	—	—	—	—	
4	0728	732.959	0.50	0.95	0.95	4.5	330	270	252	66	99	95	8 ps = -14.5
3	0732	734.65	0.55	1.05	1.05	4.5	334	268	253	59	100	95	
2	0736	736.73	0.41	0.77	0.77	4.5	337	266	252	55	101	95	
1	0740	738.69	0.22	0.42	0.42	4.0	300	266	251	53	102	95	lk ✓ @ 11.0
End	0744	740.471	—	—	—	—	—	—	—	—	—	—	= 0.005
4	0758	740.941	0.65	1.20	1.20	5.0	321	252	284	58	98	95	3 Pb = 29.66
3	0802	742.95	0.49	0.92	0.92	5.0	322	270	270	51	99	95	ps = -14.5
2	0806	745.105	0.51	0.96	0.96	5.0	320	265	271	50	101	95	vol = 0.470 ✓
1	0810	747.36	0.21	0.40	0.40	4.0	305	258	264	51	102	95	
End	0814	748.800	—	—	—	—	—	—	—	—	—	—	
4	0815	748.800	0.48	0.91	0.91	4.5	316	256	253	53	100	95	2
3	0819	751.05	0.71	1.30	1.30	5.5	320	256	251	50	101	95	
2	0823	753.41	0.77	1.45	1.45	5.5	319	270	252	51	104	95	
1	0827	755.99	0.62	1.20	1.20	5.5	314	271	253	51	106	95	
End	0831	758.770	—	—	—	—	—	—	—	—	—	—	
4	0832	758.770	0.35	0.66	0.66	3.5	309	257	252	56	104	95	1
3	0836	760.47	0.54	1.00	1.00	5.0	314	257	265	54	104	95	
2	0840	762.49	0.54	1.00	1.00	5.0	315	257	262	55	106	95	
1	0844	764.49	0.19	0.36	0.36	3.5	299	249	260	56	105	95	
End	0848	766.663	—	—	—	—	—	—	—	—	—	—	

20 BM

Version 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

Job Number 05-233
Job Name ADA ES
Run Number 3
Unit Unit 2 ESP outlet Duct
Date 8/18/05
Operator Goebel / Webber / Borensen
Sample box No. 54-2 Meter Box No. 28-2

17/26A Field Data

Read and record at the start of each test point.

Purge to: —
Purge time: —
Pitot Leak Check Initial ✓ Final ✓

Ambient Temp. °F 90
Assumed Moisture % 12
Probe Length 7'
C Factor 10 → 5.3 to reference.
Initial Leak @ 15.5 "Hg = 0.005 cfm
Final Leak @ 9.0 "Hg = 0.010 cfm

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	Orifice ΔH "H_2O Desired	P_m Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	~~Oven~~ Ghe Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Point	Remarks
4	1100	767.464	0.19	0.36	0.36	3.0	291	249	268	46	88	86	1	Pb = 29.67
3	1104	769.12	0.19	0.36	0.36	3.0	302	251	268	46	88	86		Ps = -14.5
2	1108	770.76	0.19	0.36	0.36	3.0	304	250	260	48	90	86		
1	1112	772.18	0.19	0.36	0.36	3.0	304	252	257	48	91	88		lk ✓ @ 15.0
END	1116	773.480	—	—	—	—	—	—	—	—	—	—		= 0.005
4	1131	773.916	0.46	0.86	0.86	5.0	297	256	254	61	93	89	2	vol = 0.436
3	1135	775.12	0.86	1.60	1.60	6.0	314	251	263	55	95	89		
2	1139	778.15	0.85	1.60	1.60	6.0	313	261	267	53	98	89		
1	1143	780.91	0.66	1.25	1.25	6.0	235	249	268	54	100	90		
End	1147	783.641	—	—	—	—	—	—	—	—	—	—		
4	1148	783.641	0.81	1.55	1.55	6.0	304	258	259	55	102	90	3	
3	1152	786.34	~~0.55~~ 0.65	~~1.05~~ 1.20	~~1.05~~ 1.20	5.5	313	261	252	56	104	91		
2	1156	788.83	0.67	1.25	1.25	5.5	312	266	254	56	105	92		
1	1200	791.19	0.59	1.10	1.10	5.5	258	260	263	59	105	92		lk ✓ @ 11.0
End	1204	793.91	—	—	—	—	—	—	—	—	—	—		= 0.005
4	1210	794.800	0.43	0.81	0.81	5.0	306	252	256	64	102	93	7	vol = 0.898
3	1214	796.89	0.51	0.96	0.96	5.0	330	255	254	63	103	93		
2	1218	798.85	0.52	0.98	0.98	5.0	329	257	250	63	104	93		

Pitot Tube Calibration Factor C_p 0.797 ✓ lowside
Volume Collected V_m 72.235 ✓ ft³
Water Collected V_w 199.1 ✓ ml
Time of Test T_t 128 ✓ min.
Stack Pressure P_s -14.5 ✓ "H_2O

Pitot Tube No. 53-5-2 ✓
Baro. Press. P_b 29.67 ✓ "Hg
Probe Tip Dia. D_n 0.247 ✓ in.
% CO_2 13.2 ✓ % CO 0.0 ✓
% O_2 7.2 ✓ % N_2 79.6 ✓
Area Stack A_s 21024 ✓ in²

Barometer No. 53-3 ✓ Probe Tip No. 05-233-3 ✓
Total Volume of Leak Checks After Start: 1.498 ✓ ft³
V_m = Dry Gas Meter Calibration Factor 1.019 ✓ X 70.888 ✓

{Dry Gas Meter Reading ___ ft³ – (T_t ___ min. X Leak Rate ___ cfm)}

VERSION 1
22 OCTOBER 2002

Impinger Box No. 54-2

Impinger 1	Final Weight	898.7			
	Initial Weight	745.7			
	Increase				
Impinger 2	Final Weight	768.9			
	Initial Weight	748.6			
	Increase				
Impinger 3	Final Weight	548.2			
	Initial Weight	543.5			
	Increase				
Impinger 4	Final Weight	729.4			
	Initial Weight	727.4			
	Increase				
Impinger 5	Final Weight	740.7			
	Initial Weight	738.3			
	Increase				
Impinger 6	Final Weight	1016.9			
	Initial Weight	1000.2			
	Increase				
Impinger 7	Final Weight				
	Initial Weight				
	Increase				

Water Weight Gain

Impinger 1	153.0
Impinger 2	20.3
Impinger 3	4.7
Impinger 4	2.0
Impinger 5	2.4
Impinger 6	16.7
Impinger 7	
Total	199.1 ✓ = V_w

V_w =

g SO_2 = -

V_w =

P_b =	29.67 ✓		%CO_2 =	13.2 ✓	
V_m =	72.235 ✓		%O_2 =	7.2 ✓	
V_w =	199.1 ✓		%CO =	0.0 ✓	
P_m =	1.068 ✓		%N_2 =	79.6 ✓	
Avg ΔP =	0.568 ✓		A_s =	21024 ✓	
			D_n =	0.247 ✓	
Avg$\sqrt{\Delta P}$ =	0.739 ✓		T_t =	128 ✓	
C_p =	0.797 ✓				
P_s =	-14.5 ✓	"H_2O		28.60 ✓	"Hg
T_m =	98 ✓	°F		558 ✓	°R
T_s =	312 ✓	°F		772 ✓	°R

Moisture Content: %M = 12.15 ✓ M_d = 0.8785 ✓ MW_d = 30.400 ✓ MW = 28.89 ✓

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times 72.235 \left[\frac{29.67 + \frac{1.068}{13.6}}{98 + 460}\right] = \frac{67.971 \text{ sft}^3}{0.531 \text{ scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x 199.1 ✓ = 9.398 ✓ sft³

$$\% \text{ Moisture} = \frac{Vw_{gas}}{Vm_{std} + Vw_{gas}} \times 100 = \frac{9.398}{9.398 + 67.971} \times 100 = 12.15\ \%$$

$$V_s = 5123.8 \times 0.797 \sqrt{\frac{772}{28.60 \times 28.89}} \times 0.739 = 2917 \text{ fpm}$$

$$\%I = \frac{1{,}039 \times 67.971 \times 772}{28.60 \times 0.8785 \times 2917 \times 128 \times (0.247)^2} = 95.3\ \%$$

ACFM: 425,892 ✓

SCFM: 245,498 ✓

%EA: 51.8 ✓

Run Number 3 ✓ 17/264 **FIELD DATA**

Unit Unit 2 ESP outlet Duct ✓

Date 8/18/05 ✓

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	Orifice ΔH "H_2O Desired	P_m Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	~~Oven~~ Line Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Port	Remarks
1	1222	801.013	0.41	0.76	0.76	5.0	302	251	255	63	102	94	7	
End	1226	802.42	—	—	—	—	—	—	—	—	—	—		
4	1227	802.42	0.50	0.95	0.95	5.0	327	260	259	65	103	94	8	
3	1231	804.64	0.60	1.10	1.10	5.0	332	254	254	52	103	95		
2	1235	805.80	0.45	0.85	0.85	5.0	331	255	254	49	104	95		
1	1239	807.87	0.51	0.96	0.96	5.0	320	257	252	47	105	95		lk ✓ @ 8.0
End	1243	810.425	—	—	—	—	—	—	—	—	—	—		= 0.000
4	1300	810.597	0.72	1.35	1.35	5.5	300	270	264	59	99	96	10	vol = 0.172
3	1304	813.02	0.62	1.20	1.20	5.5	339	258	241	52	100	96		Pb 29.67
2	1308	815.50	0.78	1.50	1.50	6.0	334	251	254	51	103	96		Ps = -14.5
1	1312	818.07	0.75	1.40	1.40	6.0	313	252	251	51	104	96		
End	1316	820.531	—	—	—	—	—	—	—	—	—	—		
4	1317	820.531	0.50	0.95	0.95	5.0	316	268	258	55	105	97	11	
3	1321	822.93	0.67	1.25	1.25	5.5	339	261	265	56	106	97		
2	1325	825.51	0.91	1.70	1.70	6.5	335	252	268	56	108	97		
1	1329	828.11	0.88	1.65	1.65	6.5	313	268	269	56	109	97		
End	1333	830.945	—	—	—	—	—	—	—	—	—	—		
4	1334	830.945	0.37	0.70	0.70	5.0	311	269	270	61	108	97	12	
3	1338	833.08	0.71	1.35	1.35	6.5	304	261	263	61	109	98		
2	1342	835.45	0.61	1.15	1.15	6.0	335	258	258	60	111	98		
1	1346	837.88	0.40	0.75	0.75	5.0	319	270	252	61	111	98		
End	1350	839.850	—	—	—	—	—	—	—	—	—	—		

Version 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

Job Number 05-233 ✓
Job Name ADA ES ✓
Run Number 1 TASK 1 ✓
Unit UNIT 2 ESP OUTLET ✓
Date 8-17-05 ✓
Operator BROWN/SELLERS/BORNSEN ✓
Sample box No. 51-2 Meter Box No. 53-2

ONTARIO HYDRO ~~MeHTT~~ Field Data

Read and record at the start of each test point.

Purge to: —
Purge time: —
Pitot Leak Check Initial ✓ Final ✓ ✓

Ambient Temp. °F 85
Assumed Moisture % 12
Probe Length 7'
C Factor 10 → 17 ΔH to reference.
Initial Leak @ 15.5 "Hg = 0.004 cfm ✓
Final Leak @ DO "Hg = 0.000 cfm ✓

Point	Clock Time	Dry Gas Meter, CF	ΔPs "Pitot" "H_2O	Orifice ΔH "H_2O Desired	Pm Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	Ts Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	Tm Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
12-4	1110	506.676	0.62	1.05	1.05	3.0	321	251	276	67	85	83	
12-3	1114	509.39	0.30	0.51	0.51	3.0	320	269	276	64	86	83	P_b 29.78 "Hg
12-2	1118	511.14	0.36	0.60	0.60	3.0	320	275	276	64	86	83	Pump off 1123 513.20
12-1	1122	513.00	0.30	0.51	0.51	3.0	321	276	276	64	86	83	Pump ON 1137 513.50
END	~~1126~~ 1140	515.822	~~0.85~~	~~1.45~~	—	—	—	—	—	—			P_s -14.9 "H_2O
11-4	1145	515.822	~~1.15~~	1.45 ~~0.~~	1.45	5.0	324	279	278	70	88	85	Δvol = 0.293 ✓
11-3	1149	518.48	0.80	1.35	1.35	5.0	326	278	283	66	92	85	
11-2	1153	521.29	0.90	1.50	1.50	5.0	328	280	283	68	94	86	
11-1	1157	524.03	0.72	1.20	1.20	5.0	330	274	285	65	95	85	
END	1201	527.135	—	—	—	—	—	—	—	—	—	—	leak ✓ 10"; 0.006
10-4	1228	527.620	0.50	0.84	0.84	4.5	328	289	285	71	84	84	Δvol = 0.485 ✓
10-3	1232	530.51	0.50	0.84	0.84	4.5	328	280	284	65	85	84	
10-2	1236	532.26	0.62	1.05	1.05	5.0	329	282	284	63	86	84	
10-1	1240	534.61	0.55	0.92	0.92	5.0	321	274	281	60	89	84	
END	1244	536.772	—	—	—	—	—	—	—	—	—	—	leak ✓ 10; 0.007
10-4	1245	537.311	~~0.84~~ 0.50	0.84	0.84	4.5	327	271	278	61	89	84	Δvol = 0.539 ✓
10-3	1249	539.44	0.51	0.85	0.85	4.5	327	270	276	60	92	84	P_b 29.75 "Hg
10-2	1253	541.51	0.62	1.05	1.05	5.0	330	270	275	59	94	84	P_s -14.7 "H_2O

Pitot Tube Calibration Factor C_p 0.802 ✓
Volume Collected V_m ~~56.438~~ ft³ 55.380
Water Collected V_w 150 ✓ ml
Time of Test T_t ~~120~~ 96 ✓ min.
Stack Pressure P_s -14.8 ✓ "H_2O

Pitot Tube No. 54-5-2 ✓
Baro. Press. P_b 29.77 ✓ "Hg
Probe Tip Dia. D_n 0.247 ✓ in.
% CO_2 12.8 ✓ % CO 0.0 ✓
% O_2 7.0 ✓ % N_2 80.2 ✓
Area Stack A_s 21024 ✓ in²

Barometer No. 53-3 ✓ Probe Tip No. 05-233-1 ✓
Total Volume of Leak Checks After Start: 4.833 ✓ ft³ 55.435 ✓
V_m = Dry Gas Meter Calibration Factor 0.999 ✓ X ~~56.494~~
{Dry Gas Meter Reading — ft³ – (T_t — min. X Leak Rate — cfm)}

VERSION 1
22 OCTOBER 2002

Impinger Box No. 51.2

Water Weight Gain

Impinger 1	Final Weight	835.0	
	Initial Weight	720.5	
	Increase	114.5	
Impinger 2	Final Weight	647.8	
	Initial Weight	629.0	
	Increase	18.8	
Impinger 3	Final Weight	711.6	
	Initial Weight	708.2	
	Increase	3.4	
Impinger 4	Final Weight	727.2	
	Initial Weight	725.2	
	Increase	2.0	
Impinger 5	Final Weight	749.0	
	Initial Weight	749.0	
	Increase	0.0	
Impinger 6	Final Weight	741.2	
	Initial Weight	740.2	
	Increase	1.0	
Impinger 7	Final Weight	738.0	
	Initial Weight	738.0	
	Increase	0.0	

Imp. 8: 10293 F, 10180 I, 10.3

Impinger 1	114.5
Impinger 2	18.8
Impinger 3	3.4
Impinger 4	2.0
Impinger 5	0.0
Impinger 6	1.0
Impinger 7	0.0
Imp. 8	10.3
Total	150.0 = V_w

V_w =

g SO_2 = -

V_w =

P_b =	29.77	$\%CO_2$ =	12.8
V_m =	~~56.438~~ 55.380	$\%O_2$ =	7.0
V_w =	150.0	%CO =	0.0
P_m =	0.939	$\%N_2$ =	80.2
Avg ΔP =	0.557	A_s =	21024
Avg$\sqrt{\Delta P}$ =	0.738	D_n =	0.247
C_p =	0.802	T_t =	96
P_s =	-14.8 "H_2O		28.68 "Hg
T_m =	88 °F		548 °R
T_s =	~~313~~ 325 °F		~~773~~ 785 °R

Moisture Content: %M = ~~11.55~~ 11.74 M_d = ~~0.8845~~ 0.8826 MW_d = 30.328 MW = 28.88

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times \cancel{56.438}\ 55.380 \left[\frac{29.77 + \frac{0.939}{13.6}}{88 + 460}\right] = \frac{\cancel{54.240}\ 53.223 \text{ sft}^3}{\cancel{0.565}\ 0.554 \text{ scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x 150.0 = 7.080 sft³

$$\% \text{ Moisture} = \frac{Vw_{gas}}{Vm_{std} + Vw_{gas}} \times 100 = \frac{7.080}{\cancel{54.240}\ 53.223 + 7.080} \times 100 = \cancel{11.55}\ 11.74\ \%$$

$$V_s = 5123.8 \times 0.802 \sqrt{\frac{\cancel{773}\ 785}{28.68 \times 28.88}} \times 0.738 = \cancel{2932}\ 2952 \text{ fpm}$$

$$\%I = \frac{1{,}039 \times \cancel{54.240}\ 53.223 \times \cancel{773}\ 785}{96 \times 28.68 \times \cancel{0.8845}\ 0.8826 \times \cancel{2939}\ 2952 \times (0.247)^2} = \cancel{98.4}\ 99.2\ \%$$

ACFM: ~~427738~~ 431,045

SCFM: ~~248114~~ 246,156

%EA: 49.1

VERSION 1
22 OCTOBER 2002

Run Number 1 TASK 1 ✓ O-H FIELD DATA

Unit UNIT 2 ESP OUTLET ✓

Date 8-17-05 ✓

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	Orifice ΔH "H_2O Desired	P_m Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	Oven Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
10-1	1257	543.82	0.62	1.05	1.05	5.0	330	270	275	58	94	85	
END	1301	546.400	—	—	—	—	—	—	—	—	—	—	Δvol 1.059 ✓
7-4	1321	547.459	0.36	0.60	0.60	4.0	335	277	282	70	91	86	
3	1325	549.61	0.36	0.60	0.60	4.0	336	276	281	67	93	87	
2	1329	551.32	0.46	0.78	0.78	4.0	336	276	281	67	93	87	
1	1333	553.51	0.46	0.78	0.78	4.0	310	276	284	64	94	87	
END	1337	555.294	—	—	—	—	—	—	—	—	—	—	leak ✓ 10; 0.008
3-4	1427	557.751	0.56	0.95	0.95	4.5	318	249	254	68	93	90	Δvol = 2.457 ✓
3-3	1431	560.06	0.48	0.82	0.82	4.5	319	254	256	64	94	90	
3-2	1435	562.21	0.72	1.20	1.20	5.0	318	259	251	63	98	91	
3-1	1439	564.61	0.72	1.20	1.20	5.0	317	258	254	62	100	91	
END	1443	566.944	—	—	—	—	—	—	—	—	—	—	
2-4													

Version 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

Job Number 05-233 ✓
Job Name ADA-ES ✓
Run Number 2 TASK 1 ✓
Unit UNIT 2 ESP OUTLET ✓
Date 8-17-05 ✓
Operator BROWN/WEBER/BORNSEN
Sample box No. 76 Meter Box No. 53-2 ✓

ONTARIO HYDRO ~~Meth 17~~ Field Data

Read and record at the start of each test point.

Purge to: —
Purge time: —
Pitot Leak Check Initial ✓ Final ✓ ✓

Ambient Temp. °F 88
Assumed Moisture % 12
Probe Length 7'
C Factor 10-7/17 ΔH to reference.
Initial Leak @ 15.5 "Hg = 0.006 cfm ✓
Final Leak @ 11.0 "Hg = 0.004 cfm ✓

			ΔP_s		P_m		T_s		LINE		T_m		
Point	Clock Time	Dry Gas Meter, CF	"Pitot" "H_2O	Orifice ΔH "H_2O Desired	Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	Stack Temp °F	Probe Temp °F	~~Oven~~ Temp °F	Effluent Temp °F	Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
1-4	1812	570.340	0.30	0.50	0.50	5.0	332	278	279	69	97	96	Pb 29.66
3	1816	572.13	0.55	0.92	0.92	5.5	346	276	271	64	98	96	Ps -14.5
2	1820	574.49	0.55	0.92	0.92	6.0	352	274	274	63	100	96	
1	1824	576.62	0.32	0.54	0.54	5.0	341	271	279	60	101	96	
END	1828	578.491	—	—	—	—	—	—	—	—	—	—	Δvol = 0.860 ✓
2-4	1830	579.351	0.50	0.85	0.85	6.0	336	271	278	65	100	96	
3	1834	581.45	0.85	1.45	1.45	8.0	342	270	278	63	101	96	
2	1838	584.49	0.85	1.45	1.45	8.0	340	271	279	61	101	97	
1	1842	586.93	0.68	1.15	1.15	7.0	346	270	277	60	101	97	
END	1846	589.401	—	—	—	—	—	—	—	—	—	—	leak ✓ 11.5" 0.006
3-4	1849	590.090	0.72	1.20	1.20	7.0	361	268	271	66	106	97	Δvol = 0.689 ✓
3	1853	592.52	0.65	1.10	1.10	7.0	360	269	266	65	107	96	
2	1857	594.99	0.44	0.74	0.74	5.5	362	272	268	61	107	96	
1	1901	597.02	0.72	1.20	1.20	7.0	359	273	269	60	108	97	
END	1905	599.441	—	—	—	—	—	—	—	—	—	—	leak ✓ 11.5 0.006
7-4	1926	600.901	0.36	0.62	0.62	5.0	371	278	280	69	102	97	leak ✓ 12.0 0.006
3	1930	603.11	0.32	0.54	0.54	5.0	374	271	281	61	102	97	Δvol = 1.460 ✓
2	1934	604.52	0.36	0.62	0.62	5.0	365	270	281	60	102	97	

Pitot Tube Calibration Factor C_p 0.802 ✓
Volume Collected V_m 72.282 ✓ ft³
Water Collected V_w 228.3 ✓ ml
Time of Test T_t 128 ✓ min.
Stack Pressure P_s -14.5 ✓ "H_2O

Pitot Tube No. 54-5-2 ✓
Baro. Press. P_b 29.66 ✓ "Hg
Probe Tip Dia. D_n 0.247 ✓ in.
% CO_2 13.6 ✓ % CO 0 ✓
% O_2 6.4 ✓ % N_2 80.0 ✓
Area Stack A_s 21024 ✓ in²

Barometer No. 53-3 ✓ Probe Tip No. 05-233-W ✓
Total Volume of Leak Checks After Start: 8.558 ft³ ✓
V_m = Dry Gas Meter Calibration Factor 0.999 ✓ x 72.354 ✓

{Dry Gas Meter Reading ____ ft³ – (T_t ____ min. X Leak Rate ____ cfm)}

VERSION 1
22 OCTOBER 2002

Impinger Box No. 76

			Water Weight Gain		
Impinger 1	Final Weight	921.5		Impinger 1	179.9
	Initial Weight	741.6			
	Increase			Impinger 2	22.0
Impinger 2	Final Weight	758.0			
	Initial Weight	736.0		Impinger 3	3.2
	Increase			Impinger 4	4.3
Impinger 3	Final Weight	744.0	V_w = g SO_2 = - V_w =	Impinger 5	2.3
	Initial Weight	740.8			
	Increase			Impinger 6	0.4
Impinger 4	Final Weight	725.0	Imp 8 1015.2 I / 1029.5 F	Impinger 7	1.9
	Initial Weight	720.7		Imp 8	14.3
	Increase			Total	228.3 = V_w
Impinger 5	Final Weight	737.9			
	Initial Weight	735.6			
	Increase				
Impinger 6	Final Weight	623.2			
	Initial Weight	622.8			
	Increase				
Impinger 7	Final Weight	744.0			
	Initial Weight	742.1			
	Increase				

P_b =	29.66	$\%CO_2$ =	13.6
V_m =	72.282	$\%O_2$ =	6.4
V_w =	228.3	%CO =	0.0
P_m =	0.977	$\%N_2$ =	80.0
Avg ΔP =	0.578	A_s =	21024
		D_n =	0.247
Avg$\sqrt{\Delta P}$ =	0.751	T_t =	128
C_p =	0.802		
P_s =	-14.5 "H_2O	28.59	"Hg
T_m =	101 °F	561	°R
T_s =	343 °F	803	°R

Moisture Content: %M = 13.75 M_d = 0.8625 MW_d = 30.432 MW = 28.72

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times 72.282 \left[\frac{29.66 + \frac{0.977}{13.6}}{101 + 460}\right] = \frac{67.614 \text{ sft}^3}{0.528 \text{ scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x 228.3 = 10.776 sft³

$$\% \text{ Moisture} = \frac{Vw_{gas}}{Vm_{std} + Vw_{gas}} \times 100 = \frac{10.776}{10.776 + 67.614} \times 100 = 13.75\ \%$$

$$V_s = 5123.8 \times 0.802 \sqrt{\frac{803}{28.59 \times 28.72}} \times 0.751 = 3052 \text{ fpm}$$

$$\%I = \frac{1{,}039 \times 803 \times 67.614}{0.8625 \times 3052 \times 28.59 \times 128 \times (0.247)^2} = 96.0\ \%$$

ACFM: 445572

SCFM: 242,361

%EA: 43.2

Run Number 2 TASK 1 ✓ O-HYDRO **FIELD DATA**

Unit UNIT 2 ESP OUTLET ✓

Date 8-17-05 ✓

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	Orifice ΔH "H_2O Desired	P_m Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	~~Oven~~ LINE Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
7-1	1938	606.33	0.44	0.74	0.74	5.5	343	278	280	60	102	97	
END	1942	608.284	—	—	—	—	—	—	—	—	—	—	leak ✓ 11.5" 0.004
8-4	1956	609.371	0.36	0.62	0.62	5.0	307	279	276	69	100	97	leak ✓ 12" 0.004
3	2000	611.34	0.36	0.62	0.62	5.0	320	278	273	68	101	97	P_b 29.66 "Hg
2	2004	613.11	0.40	0.68	0.68	5.5	368	269	276	64	102	97	P_s -14.5 "H_2O
1	2008	614.97	0.45	0.75	0.75	5.5	363	271	272	61	103	97	ΔVol = 1.087 ✓
END	2012	617.011	—	—	—	—	—	—	—	—	—	—	ΔVol = 2.070 ✓
10-4	2016	619.081	0.55	0.95	0.95	6.0	327	259	266	68	104	97	
3	2020	621.39	0.74	1.25	1.25	7.0	333	267	272	64	107	97	
2	2024	623.82	0.90	1.50	1.50	7.5	336	272	266	63	109	97	
1	2028	626.49	0.85	1.45	1.45	7.5	338	271	271	61	109	98	
END	2032	629.411	—	—	—	—	—	—	—	—	—	—	
11-4	2034	630.550	0.50	0.85	0.85	6.0	339	267	271	67	110	97	ΔVol = 1.139 ✓
3	2038	632.69	0.74	1.25	1.25	7.0	347	269	271	61	110	97	
2	2042	635.41	0.74	1.25	1.25	7.0	341	275	276	60	112	98	
1	2046	637.84	0.80	1.35	1.35	7.5	345	271	272	60	111	98	
END	2050	640.571	—	—	—	—	—	—	—	—	—	—	ΔVol = 1.253 ✓
12-4	2052	641.824	0.56	0.95	0.95	6.5	323	270	278	64	108	98	
3	2056	644.11	0.82	1.35	1.35	7.5	329	270	279	61	109	98	
2	2100	646.82	0.56	0.95	0.95	6.5	333	270	279	60	109	98	
1	2104	648.91	0.56	0.95	0.95	6.5	330	272	274	61	109	98	
END	2108	651.252	—	—	—	—	—	—	—	—	—	—	

Version 1
22 OCTOBER 2002

METCO ENVIRONMENTAL

O-HYDRO / M17 **Field Data**

Job Number 05-233 ✓
Job Name ADA-ES ✓
Run Number 3 TASK 1 ✓
Unit UNIT 2 ESP OUTLET ✓
Date 8-18-05 ✓
Operator BROWN/SELLERS/BORNSEN ✓
Sample box No. 76 Meter Box No. 53-2 ✓

Read and record at the start of each test point.

Purge to: —
Purge time: —
Pitot Leak Check Initial ✓ Final ✓ ✓

Ambient Temp. °F 90
Assumed Moisture % 12
Probe Length 7'
C Factor 10-7 1.8 ΔH to reference.
Initial Leak @ 15.0 "Hg = 0.005 cfm ✓
Final Leak @ 10.0 "Hg = 0.007 cfm ✓

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	Orifice ΔH "H_2O Desired	P_m Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	~~Oven~~ LINE Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
12-4	1120	655.220	0.26	0.42	0.42	4.5	326	249	251	66	94	92	P_b 29.67 "Hg
3	1124	657.03	0.80	1.45	1.45	6.5	328	256	249	62	95	92	P_s -14.5
2	1128	659.34	0.44	0.80	0.80	5.5	325	252	249	59	97	92	
1	1132	661.38	0.44	0.80	0.80	5.5	326	253	252	58	97	92	
END	1136	663.441	—	—	—	—	—	—	—	—	—	—	ΔVol = 0.520 ✓
11-4	1137	663.961	0.40	0.72	0.72	5.0	328	251	261	55	100	93	
3	1141	665.97	0.56	1.00	1.00	5.5	330	251	264	55	101	93	
2	1145	668.29	0.90	1.60	1.60	7.0	335	258	268	55	104	93	
1	1149	671.01	0.90	1.60	1.60	7.0	327	261	270	55	104	94	
END	1153	673.833	—	—	—	—	—	—	—	—	—	—	leak ✓ 10; 0.004
8-4	1158	675.832	0.50	0.90	0.90	6.0	327	250	253	59	104	95	ΔVol = 1.999 ✓
3	1202	678.09	0.55	1.00	1.00	6.0	328	251	253	57	106	96	
2	1206	680.27	0.55	1.00	1.00	6.0	330	251	253	57	106	96	
1	1210	682.62	0.50	0.90	0.90	6.0	334	258	254	58	107	97	
END	1214	684.861	—	—	—	—	—	—	—	—	—	—	leak ✓ 11; 0.007
10-4	1220	687.080	0.83	1.50	1.50	7.0	333	256	250	57	107	97	ΔVol = 2.219 ✓
3	1224	689.79	0.85	1.55	1.55	7.0	334	256	252	57	107	97	
2	1228	692.49	0.64	1.15	1.15	6.0	337	261	248	58	109	98	

Pitot Tube Calibration Factor C_p 0.802 ✓
Volume Collected V_m 72.749 ✓ ft^3
Water Collected V_w 277.6 ✓ ml
Time of Test T_t 128 ✓ min.
Stack Pressure P_s -14.5 ✓ "H_2O

Pitot Tube No. 54-5-2 ✓
Baro. Press. P_b 29.67 ✓ "Hg
Probe Tip Dia. D_n 0.247 ✓ in.
% CO_2 13.2 ✓ % CO 0.0 ✓
% O_2 7.2 ✓ % N_2 79.6 ✓
Area Stack A_s 21024 ✓ in^2

Barometer No. 53-3 ✓ Probe Tip No. 05-233-1 ✓
Total Volume of Leak Checks After Start: 8.679 / ft^3
V_m = Dry Gas Meter Calibration Factor 0.999 ✓ x 72.822 ✓

{Dry Gas Meter Reading — ft^3 – (T_t — min. X Leak Rate ____ cfm)}

VERSION 1
22 OCTOBER 2002

Impinger Box No. 76

			Water Weight Gain		
Impinger 1	Final Weight	914.6		Impinger 1	174.8
	Initial Weight	739.8			
	Increase			Impinger 2	23.1
Impinger 2	Final Weight	763.9		Impinger 3	3.9
	Initial Weight	740.8			
	Increase			Impinger 4	2.6
Impinger 3	Final Weight	746.2	V_w =		
	Initial Weight	742.3	g SO_2 = - –	Impinger 5	-0.1
	Increase		V_w =	Impinger 6	-0.8
Impinger 4	Final Weight	722.7	Imp. 8 1042.7		
	Initial Weight	720.1	1028.6	Impinger 7	0.0
				Imp 8	14.1
	Increase			Total	217.6 = V_w
Impinger 5	Final Weight	747.1			
	Initial Weight	747.2			
	Increase				
Impinger 6	Final Weight	741.0			
	Initial Weight	741.8			
	Increase				
Impinger 7	Final Weight	623.5			
	Initial Weight	623.5			
	Increase				

P_b =	29.67 ✓	$\%CO_2$ =	13.2 ✓
V_m =	72.749 ✓	$\%O_2$ =	7.2 ✓
V_w =	217.6 ✓	%CO =	0.0 ✓
P_m =	1.029 ✓	$\%N_2$ =	79.6 ✓
Avg ΔP =	0.570 ✓	A_s =	21024 ✓
		D_n =	0.247 ✓
Avg$\sqrt{\Delta P}$ =	0.745 ✓	T_t =	128 ✓
C_p =	0.802 ✓		
P_s =	-14.5 ✓ H_2O	28.60 ✓ "Hg	
T_m =	102 ✓ °F	562 ✓ °R	
T_s =	330 ✓ °F	790 ✓ °R	

Moisture Content: %M = 13.13 ✓ M_d = 0.8687 ✓ MW_d = 30.400 ✓ MW = 28.77 ✓

$$Vm_{std} = 17.65\ Vm \left[\frac{P_b + \frac{P_m}{13.6}}{T_m + 460}\right] = 17.65 \times 72.749 \left[\frac{29.67 + \frac{1.029}{13.6}}{102 + 460}\right] = \frac{67.961 \text{ sft}^3}{0.531 \text{ scfm}}$$

Vw_{gas} = 0.0472 x Vw = 0.0472 x 217.6 ✓ = 10.271 ✓ sft^3

$$\%\ Moisture = \frac{Vw_{gas}}{Vm_{std} + Vw_{gas}} \times 100 = \frac{10.271}{10.271 + 67.961} \times 100 = 13.13\ \%$$

$$V_s = 5123.8 \times 0.802 \sqrt{\frac{790}{28.60 \times 28.77}} \times 0.745 = 3000 \text{ fpm}$$

ACFM: 437962 ✓

$$\%I = \frac{1{,}039 \times 67.961 \times 790}{0.8687 \times 3000 \times 28.60 \times 128 \times (0.247)^2} = 95.8\ \%$$

SCFM: 243978 ✓

%EA: 51.8 ✓

Run Number 3 ✓

Unit UNIT 2 ESP OUTLET ✓

Date 8-18-05 ✓

O-HYDRO M.17 **FIELD DATA**

Point	Clock Time	Dry Gas Meter, CF	ΔP_s "Pitot" "H_2O	Orifice ΔH "H_2O Desired	P_m Orifice ΔH "H_2O Actual	Pump Vacuum "Hg Gauge	T_s Stack Temp °F	Probe Temp °F	LINE ~~Oven~~ Temp °F	Effluent Temp °F	T_m Dry Gas Temp °F Inlet	Dry Gas Temp °F Outlet	Remarks
10-1	1232	695.16	0.60	1.10	1.10	6.0	338	~~238~~ 264	251	57	109	99	
END	1236	697.511	—	—	—	—	—	—	—	—	—	—	leak ✓ 11"; 0.009
4-4	1255	699.491	0.34	0.62	0.62	5.0	336	272	248	68	108	99	Δvol = 1.98 ✓
3	1259	701.43	0.44	0.80	0.80	5.5	337	268	249	66	100	100	Pb 29.67"Hg
2	1303	703.41	0.52	0.94	0.94	5.5	341	261	251	64	104	100	Ps -14.5
1	1307	705.69	0.48	0.86	0.86	5.5	337	258	254	64	106	100	
END	1311	707.829	—	—	—	—	—	—	—	—	—	—	
3-4	1313	708.411	0.80	1.45	1.45	7.0	352	267	266	61	107	99	Δvol = 0.582 ✓
3	1317	711.13	0.52	0.94	0.94	6.0	358	263	270	62	109	99	
2	1321	713.49	0.74	1.35	1.35	6.5	330	260	264	62	109	100	
1	1325	716.05	0.76	1.40	1.40	7.0	327	259	260	59	109	101	
END	1329	718.600	—	—	—	—	—	—	—	—	—	—	
2-4	1330	719.311	0.33	0.60	0.60	5.0	318	253	254	62	110	101	Δvol = 0.711 ✓
3	1334	721.19	0.35	0.62	0.62	5.0	320	254	254	60	110	101	
2	1338	722.97	0.46	0.82	0.82	5.5	325	253	250	60	110	101	
1	1342	725.02	0.90	1.60	1.60	7.0	324	252	250	60	110	101	
END	1346	727.521	—	—	—	—	—	—	—	—	—	—	Δvol = 0.668 ✓
1-4	1347	728.189	0.25	0.45	0.45	4.5	314	250	249	61	110	101	
3	1351	729.79	0.60	1.10	1.10	6.0	321	252	249	60	110	101	
2	1355	732.132	0.60	1.10	1.10	6.0	322	253	249	60	110	101	
1	1359	734.71	0.44	0.80	0.80	5.5	323	254	250	60	110	101	
END	1403	736.721	—	—	—	—	—	—	—	—	—	—	

Version 1
22 OCTOBER 2002

PRELIMINARY VELOCITY TRAVERSE DATA
AND
SAMPLING LOCATION DATA

Job Number 05-233 TASK 2
Job Name ADAMS
Sampling Location Inlet Duct Unit #2
Date 8-16-05 Time 1030

Stack Height 198' ft.
Sampling Port Height Above Ground 198' ~~6 1/4"~~ ft.

	Port A	Port B	Port C	Port D	Average
Port & Inside Diameter (in.)	94 1/4"	on All {A,B,C,D,G,I,J,K)			94 1/4"
Port & Wall Thickness (in.)	21 1/4"	on All (A,B,C,D,G,I,J,K)			21 1/4"
Inside Stack Diameter (in.)	73"	on All (A,B,C,D,G,I,J,K)			73" x288"

Sampling Ports are 6 ft. 6 1/4 in. (0.67 stack diameters) ~~downstream~~ upstream from disturbance (inlet, constriction, bend, expansion)

Sampling Ports are 25 ft. 4 in. (~~2.60~~ 2.61 stack diameters) ~~upstream~~ downstream from disturbance (outlet, constriction, bend, expansion)

Point Number	Percent Diameter	Distance from Ref. Point (decimal in.)	Distance from Ref. Point (fractional in.)	Right to Left Port A $\Delta P/T_s/\alpha$	Port B $\Delta P/T_s/\alpha$	Port C $\Delta P/T_s/\alpha$	Port D $\Delta P/T_s/\alpha$
1	–	9.125 ✓	9 1/8" ✓	1.30/308/+5	1.20/310/+10	1.10/311/+5	1.45/312/+8
2	–	27.375 ✓	27 3/8 ✓	1.40/307/+7	1.10/310/+5	1.25/310/0	1.40/311/+10
3	–	45.625 ✓	45 5/8 ✓	1.45/308/+5	1.20/310/+3	1.30/309/+7	1.40/311/+4
4	–	63.875 ✓	63 7/8 ✓	1.30/309/+6	1.30/308/+4	1.25/308/+6	1.25/308/+3
5				/ /	/ /	/ /	/ /
6				Port G	Port I	Port J	Port K
~~7~~ 1	–	9.125 ✓	9 1/8 ✓	0.35/301/-11	1.00/327/-5	0.85/330/-5	1.40/332/0
~~8~~ 2	–	27.375 ✓	27 3/8 ✓	0.60/322/-10	1.10/326/0	0.95/330/-3	1.35/331/0
~~9~~ 3	–	45.625 ✓	45 5/8 ✓	0.71/321/-6	1.20/326/+5	1.20/330/-2	1.40/329/-1
~~10~~ 4	–	63.875 ✓	63 7/8 ✓	0.75/319/-7	1.25/324/+4	1.30/328/-4	1.25/326/-3
11				/ /	/ /	/ /	/ /
12				/ /	/ /	/ /	/ /
13				/ /	/ /	/ /	/ /
14				/ /	/ /	/ /	/ /
15				/ /	/ /	/ /	/ /
16				/ /	/ /	/ /	/ /
17				/ /	/ /	/ /	/ /
18				/ /	/ /	/ /	/ /
19	* Port G was odd compared to			/ /	/ /	/ /	/ /
20	rest of ports			/ /	/ /	/ /	/ /
21				/ /	/ /	/ /	/ /
22				/ /	/ /	/ /	/ /
23				/ /	/ /	/ /	/ /
24				/ /	/ /	/ /	/ /

Pitot Tube No. 28-12-2 ✓
C_p = 0.805 ✓
P_b = 29.76 "Hg
P_s = -14.2 "H_2O 28.72 ✓ "Hg
A_s = 21,024 ✓ in.^{2}

Average ΔP 1.166 ✓
Average $\Delta P^{1/2}$ 1.071 ✓
Average T_s 317 ✓ °F
Average α 4.88 ✓ degrees

VERSION 1
22 OCTOBER 200

PRELIMINARY VELOCITY TRAVERSE DATA
AND
SAMPLING LOCATION DATA

Job Number 05- 237

Job Name ADA

OUTLET

Sampling Location ESP OUTLET UNIT 2

Date 8/15/05 Time 1100

Stack Height 198 ft.

Sampling Port Height Above Ground 198 ft.

192+6

	Port A	Port B	Port C	Port D	Average
Port & Inside Diameter (in.)					~~94~~ 95
Port & Wall Thickness (in.)					22
Inside Stack Diameter (in.)					~~72~~ 73 x 288"

Sampling Ports are 6 ft. 11 in. (~~0.72~~ 0.71 ~~0.71~~ stack diameters) downstream from disturbance (inlet, constriction, bend, expansion)

Sampling Ports are 3 ft. 2 in. (0.33 ~~0.33~~ stack diameters) upstream from disturbance (outlet, constriction, bend, expansion)

De = ~~116.5~~ ~~115.2~~ 116.5

Point Number	Percent Diameter	Distance from Ref. Point (decimal in.)	Distance from Ref. Point (fractional in.)	Port ~~A~~ 1 ΔP/T_s/α	Port ~~B~~ 2 ΔP/T_s/α	Port ~~C~~ 3 ΔP/T_s/α	Port ~~D~~ 4 ΔP/T_s/α
1		~~12.167~~	~~12 3/16~~	/ /	/ /	/ /	/ /
2		~~36.5~~	~~36 1/2~~	/ /	/ /	/ /	/ /
3		~~60.833~~	~~60 13/16~~	/ /	/ /	/ /	/ /
4				/ /	/ /	/ /	/ /
5				/ /	/ /	/ /	/ /
6				/ /	/ /	/ /	/ /
7				/ /	/ /	/ /	/ /
8				/ /	/ /	/ /	/ /
9				/ /	/ /	/ /	/ /
10				K /12/	K /11/	H /8/	10/
11		~~9.125~~	1	0.30 /315/ -3°	0.90/323/ -2	0.25/317/ 2	/ /
12		~~27.375~~	2	0.36 /324/ -3°	0.95 /323/ -5	0.47/319/ 5	/ /
13		~~45.625~~	3	0.84 /321/ -5°	0.74/319/ -8	0.56/315/ 5	/ /
14		~~63.875~~	4	0.30/321/ -5°	0.38 /316/ -10	0.50/312/ 5	/ /
15				/ /	/ /	/ /	/ /
16				/ /	/ /	/ /	/ /
17				/ /	/ /	/ /	/ /
18				/ /	/ /	/ /	/ /
19				/ /	/ /	/ /	/ /
20				1 / /	2/ /	3/ /	4 / /
21		9.125 ✓	9 1/8 ✓	0.17 /275/ 2°	0.75/293/ -3°	/ /	0.56 /305/ 2°
22		27.375 ✓	27 3/8 ✓	0.61 /295/ 2°	0.89/307/ -2°	/ /	0.52/309/ 5°
23		45.625 ✓	45 5/8 ✓	0.50 /293/ 2°	0.74/307/ -5°	/ /	0.70/306/ 10°
24		63.875 ✓	63 7/8 ✓	0.11 /283/ 5°	0.58/295/ -17°	/ /	0.68 /296/ 12°

Pitot Tube No. 54-10-1 ✓

C_p = 0.806 ✓

P_b = 29.74 "Hg

P_s = -14.9 "H_2O 28.66 ✓ "Hg

A_s = 21024 ✓ in.² ✓

Average ΔP 0.557 ✓

Average $ΔP^{1/2}$ 0.727 ✓

Average T_x 308 ✓ °F 768

Average α ~~0.46~~ 5.2 ✓ degrees

VERSION 1
22 OCTOBER 2002

APPENDIX E

Analytical Data

METCO Environmental

Particulate Analysis Summary

Job Number 05 - 233 Task 1 Date Analysis Completed 8-29-05

Job Name ADA-ES Unit Tested #2 ESP Inlet

Location Newark, Av.

Run No.	1	2	3		
Particulate on ~~Filter~~ Thimble (mg)	4,577.7	4,548.6	6,278.1		
Particulate in Front Wash (mg)*	1788.3	849.0	666.4		
MF (mg)	6,366.0	5,397.6	6,944.5		
Particulate in Impinger #1 (mg)					
MT (mg)					

M. Ganter
Analyst

* Less Acetone Residue

METCO Environmental

Particulate Analysis EPA Method ~~5~~ 17

Front Wash

Job Number 05-233 task 1

Location Newark, OH.

Job Name ADA-ES

Unit Tested #2 ESP Inlet

Desiccator Time In	1635 8/24				
Desiccator Time Out	1315 8/25	815 8/26			

Run No. 1	Volume (ml) 335				
Final Weight (g)	127.3258	127.3262	✓		
Initial Weight (g)	125.5358	125.5351			
Particulate Weight (g)	1.7907	1.7911			

1.7731

Particulate Average (mg) 1790.9
Less Acetone Blank (mg) 2.6
Total Particulate (mg) 1788.3

Run No. 2	Volume (ml) 168				
Final Weight (g)	122.0104	122.0108	✓		
Initial Weight (g)	121.1603	121.1603			
Particulate Weight (g)	0.8501	0.8505			

Particulate Average (mg) 850.3
Less Acetone Blank (mg) 1.3
Total Particulate (mg) 849.0

Run No. 3	Volume (ml) 163				
Final Weight (g)	174.8958	174.8957	✓		
Initial Weight (g)	174.2281	174.2281			
Particulate Weight (g)	0.6677	0.6676			

Particulate Average (mg) 667.7
Less Acetone Blank (mg) 1.3
Total Particulate (mg) 666.4

Acetone Blank	Volume (ml)				
Final Weight (g)					
Initial Weight (g)					
Difference (g)					

Mettler AE240

Average (mg) ________
* mg/l________

* Note: If greater than 7.9 mg/l, use 7.9 mg/l.

MG
Analyst

METCO Environmental

Particulate Analysis EPA Method ~~5~~/17

Stack ~~Filters~~ thimbles

Job Number 05-233 TSK1

Job Name ADA-ES

Location Newark, Ar.

Unit Tested #2 ESP Inlet

Desiccator Time In	8/23 1430				
Desiccator Time Out	8/24 1620	830 8/26			

Run No. 1 Filter No. Q 376

Filter & Particulate + Tare Weight (g)	7.6833	7.6820	✓		
Tare Weight (g)					
Filter & Particulate (g)					

Filter & Particulate Average (g) 7.6827

Initial Filter Weight (g) 3.1050

Total Particulate (mg) 4577.7 ✓

Run No. 2 Filter No. Q 388

Filter & Particulate + Tare Weight (g)	7.6477	7.6471	✓		
Tare Weight (g)					
Filter & Particulate (g)					

Filter & Particulate Average (g) 7.6474

Initial Filter Weight (g) 3.0988

Total Particulate (mg) 4548.6 ✓

Run No. 3 Filter No. Q 389

Filter & Particulate + Tare Weight (g)	9.3482	9.3472	✓		
Tare Weight (g)					
Filter & Particulate (g)					

Filter & Particulate Average (g) 9.3477

Initial Filter Weight (g) 3.0696

Total Particulate (mg) 6278.1 ✓

Run No. ______ Filter No. ______

Filter & Particulate + Tare Weight (g)					
Tare Weight (g)					
Filter & Particulate (g)					

Mettler AE240

Filter & Particulate Average (g) ______

Initial Filter Weight (g) ______

Total Particulate (mg) ______

MH

Analyst

METCO Environmental

Particulate Analysis Summary

Job Number 05-233 Task1

Date Analysis Completed 8-29-05

Job Name ADA-ES

Unit Tested #2 ESP Outlet

Location Newark, Ar.

Run No.	1	2	3		
Particulate on ~~Filter~~ thimble (mg)	22.3	46.3	50.7		
Particulate in Front Wash (mg)*	25.1	4.0	5.1		
MF (mg)	47.4	50.3	55.8		
Particulate in Impinger #1 (mg)					
MT (mg)					

M. Ganter
Analyst

* Less Acetone Residue

METCO Environmental

Particulate Analysis EPA Method ~~5~~ /7

Front Wash

Job Number 05-233 task1 Location Newark, Ar.

Job Name ADA - ES Unit Tested #2 ESP Outlet

Desiccator Time In	900 8/24				
Desiccator Time Out	1350 8/24	1540 8/25			

Run No. 1	Volume (ml) 95				
Final Weight (g)	120.8240	120.8243	✓		
Initial Weight (g)	120.7983	120.7983			
Particulate Weight (g)	0.0257	0.0260			

Particulate Average (mg) 25.9

Less Acetone Blank (mg) 0.8

Total Particulate (mg) 25.1 ✓

Run No. 2	Volume (ml) 58				
Final Weight (g)	139.0173	139.0172 ✓			
Initial Weight (g)	139.0128	139.0128			
Particulate Weight (g)	0.0045	0.0044			

Particulate Average (mg) 4.5

Less Acetone Blank (mg) 0.5

Total Particulate (mg) 4.0 ✓

Run No. 3	Volume (ml) 95				
Final Weight (g)	168.6031	168.6036 ✓			
Initial Weight (g)	168.5975	168.5975			
Particulate Weight (g)	0.0056	0.0061			

Particulate Average (mg) 5.9

Less Acetone Blank (mg) 0.8

Total Particulate (mg) 5.1 ✓

Acetone Blank ✓	Volume (ml) 192				
Final Weight (g)	172.2511	172.2513 ✓			
Initial Weight (g)	172.2468	172.2468			
Difference (g)	0.0043	0.0045			

Mettler AE240

Average (mg) 4.4

* mg/l 22.9 ✓

* Note: If greater than 7.9 mg/l, use 7.9 mg/l.

mg

Analyst

METCO Environmental

Particulate Analysis EPA Method ~~5~~ 17

Thimbles

~~Stack Filters~~

Job Number 05-233 Tsk1

Job Name ADA-ES

Location Newark, Ar.

Unit Tested #2ESP Outlet

Desiccator Time In	8/23 1430				
Desiccator Time Out	8/24 1625	850 8/26			

Run No. 1	Filter No. Q 392				
Filter & Particulate + Tare Weight (g)	2.9731	2.9731	✓		
Tare Weight (g)					
Filter & Particulate (g)					

Filter & Particulate Average (g) 2.9731
Initial Filter Weight (g) 2.9508
Total Particulate (mg) 22.3 ✓

Run No. 2	Filter No. Q 398				
Filter & Particulate + Tare Weight (g)	3.1841	3.1836	✓		
Tare Weight (g)					
Filter & Particulate (g)					

Filter & Particulate Average (g) 3.1839
Initial Filter Weight (g) 3.1376
Total Particulate (mg) 46.3 ✓

Run No. 3	Filter No. Q 391				
Filter & Particulate + Tare Weight (g)	3.1403	3.1394	3.1390 ✓		
Tare Weight (g)					
Filter & Particulate (g)					

Filter & Particulate Average (g) 3.1392
Initial Filter Weight (g) 3.0885
Total Particulate (mg) 50.7 ✓

Run No. Blank	Filter No. Q 382				
Filter & Particulate + Tare Weight (g)	3.0980	3.0980			
Tare Weight (g)					
Filter & Particulate (g)					

Mettler AE240

Filter & Particulate Average (g) 3.0980
Initial Filter Weight (g) 3.0960
Total Particulate (mg) 2.0 ✓

mb

Analyst

METCO ENVIRONMENTAL

LABORATORY QUALITY ASSURANCE DATA

BALANCE ID Mettler AE240

DATE & TIME		100g STD	1.0g STD	0.5g STD	ANALYST	REMARKS
8/26/05 0815	Actual (g)	100.0000	1.0000	0.5000	mh	
	Difference (mg)	0	0	0		
8/29/05 0910	Actual (g)	100.0000	1.0000	0.5000	mh	
	Difference (mg)	0	0	0		
8/30/05 0815	Actual (g)	100.0000	1.0000	0.5000	mh	
	Difference (mg)	0	0	0		
8/31/05 0758	Actual (g)	100.0000	1.0000	0.5000	mh	
	Difference (mg)	0	0	0		
815 9-1-05	Actual (g)	100.0000	1.0000	0.5000	mh	
	Difference (mg)	0	0	0		
845 9/2/05	Actual (g)	100.0000	1.0000	0.5000	mh	
	Difference (mg)	0	0	0		
9/5/05 830	Actual (g)	100.0000	1.0000	0.5000	mh	
	Difference (mg)	0	0	0		
9/6/05 845	Actual (g)	99.9999	1.0000	0.5000	mh	
	Difference (mg)	-0.1	0	0		
	Actual (g)					
	Difference (mg)					
	Actual (g)					
	Difference (mg)					
	Actual (g)					
	Difference (mg)					
	Actual (g)					
	Difference (mg)					

METCO ENVIRONMENTAL

LABORATORY QUALITY ASSURANCE DATA

BALANCE ID Mettler AE240

DATE & TIME		100g STD	1.0g STD	0.5g STD	ANALYST	REMARKS
8/8/05	Actual (g)	100.0000	1.0000	0.5000	mk	
	Difference (mg)	0	0	0		
8/9/05 1015	Actual (g)	100.0000	1.0000	0.5000	mk	
	Difference (mg)	0	0	0		
8/11/05 0935	Actual (g)	100.0000	1.0000	0.5000	mk	
	Difference (mg)	0	0	0		
8/12/05 1010	Actual (g)	100.0000	1.0000	0.5000	mk	
	Difference (mg)	0	0	0		
8/15/05 0908	Actual (g)	100.0000	1.0000	0.5000	mk	
	Difference (mg)	0	0	0		
1130 8/16/05	Actual (g)	100.0000	1.0000	0.5000	mk	
	Difference (mg)	0	0	0		
945 8/17/05	Actual (g)	100.0000	1.0000	0.5000	mk	tech came to service WBC-1 + WDC-2
	Difference (mg)	0	0	0		
1410 8/18/05	Actual (g)	100.0000	1.0000	0.5000	mk	
	Difference (mg)	0	0	0		
830 8/19/05	Actual (g)	100.0000	1.0000	0.5000	mk	
	Difference (mg)	0	0	0		
835 8/22/05	Actual (g)	100.0000	1.0000	0.5000	mk	
	Difference (mg)	0	0	0		
8/23/05 920	Actual (g)	100.0000	1.0000	0.5000	mk	
	Difference (mg)	0	0	0		
950 8/24/05	Actual (g)	100.0000	1.0000	0.5000	mk	
	Difference (mg)	0	0	0		
8/25 1330		100.0000	1.0000	0.5000	mk	
		0	0	0		

05-233 task 1
ADA-ES
Newark, ar-Ind

9-6-05
#2 ESP Inlet

RUN	Imp	Vol	DILN	PPM F	PPM F	PPM AVG	% RD	PPM Cl	PPM Cl	PPM avg.	% RD	PPM Br	PPM Br	PPM avg.	% RD	Total ug HF	Total ug HCl	Total ug HBr	Total ug Cl_2*	Total ug Br_2*
1	1-3	416	1	2.797	2.789	2.793	0.3	1.968	1.988	1.978	1.0	0.172	0.170	0.171	1.2	1,223.040	846.060	72.026	–	–
	4,5	256	2	-	-	-		ND	ND	ND	-	ND	ND	ND	-				ND	ND
								Run 1 total ug								1,223.0	846.1	72.0	ND	ND
2	1-3	456	1	1.906	1.886	1.896	1.1	1.714	1.764	1.739	2.9	ND	ND	ND	-	910.080	815.353	ND	–	–
	4,5	298	2	-	-			ND	ND	ND	-	ND	ND	ND	-				ND	ND
								Run 2 total ug								910.1	815.4	ND	ND	ND
3	1-3	465	1	2.399	2.418	2.4085	0.8	2.438	2.426	2.432	0.5	0.109	0.112	0.1105	2.7	1,178.897	1,162.781	52.026	–	–
	4,5	268	2	-	-			ND	ND	ND	-	ND	ND	ND	-				ND	ND
								Run 3 total ug								1,178.9	1,162.8	52.0	ND	ND

SPIKE	ppm F	ppm F	% RD	ppm Cl	ppm Cl	% RD	ppm Br	ppm Br	% RD	% Recovery F		% Recovery Cl		% Recovery Br	
R1I4,5@2x+1ppm	-	-		1.055	1.051	0.4	1.008	0.986	2.2	-	-	105.5	105.1	100.8	98.6
R3I1-3@2x+1.25ppm	2.448	2.460	0.5	2.375	2.400	1.0	1.301	1.302	0.1	99.5	100.5	92.7	94.7	99.7	99.7

* Initial pH : Run 1 Imp 4+5, 7.5 Run 2 Imp 4+5, 7 Run 3 Imp 4+5, 6 The pH's were adjusted to basic and then sodium thiosulfate added.

05-233 Task1
ADA-ES
Newark, Av-End

9-6-05
2 ESP Outlet

Run	Imp	Vol	Diln	ppm F	ppm F	ppm Avg.	% RD	ppm Cl	ppm Cl	ppm avg.	% RD	ppm Br	ppm Br	ppm avg.	% RD	Total ug HF	Total ug HCl	Total ug HBr	Total ug Cl_2*	Total ug Br_2*
1	1-3	467	1	6.402	6.302	6.352	1.6	2.815	2.764	2.7895	1.8	0.246	0.247	0.2465	0.4	3,122.509	1,339.444	116.556		
	4,5	240	2	-	-			ND	ND	ND	-	ND	ND	ND	-				ND	ND
								Run 1 total ug								3,122.5	1,339.4	116.6	ND	ND
2	1-3	428	1	3.554	3.680	3.617	3.5	2.404	2.266	2.335	5.9	ND	ND	ND	-	1,629.554	1,027.571	ND		
	4,5	260	2	-	-			ND	ND	ND	-	ND	ND	ND	-				ND	ND
								Run 2 total ug								1,629.6	1,027.6	ND	ND	ND
3	1-3	475	1	5.232	5.237	5.2345	0.1	2.946	2.968	2.957	0.7	0.201	0.200	0.2005	0.5	2617.250	1,444.196	96.429		
	4,5	260	2	-	-			ND	ND	ND	-	ND	ND	ND	-				ND	ND
								Run 3 total ug								2617.3	1,444.2	96.4	ND	ND

Spike	ppm F	ppm F	% RD	ppm Cl	ppm Cl	% RD	ppm Br	ppm Br	% RD	% Recovery F		% Recovery Cl		% Recovery Br	
R2I1-3@2x+1ppm	2.876	2.894	0.6	2.125	2.156	1.4	1.042	1.060	1.7	106.8	108.6	95.8	98.9	104.2	106.0
R2I4,5@2x+1ppm	-	-		1.080	1.007	7.0	0.979	1.024	4.5	-	-	108.0	100.7	97.9	102.4

* Initial pH's Run 1 Imp 4+5, pH 12-14 Run 2 Imp 4+5, pH 7 Run 3 Imp 4+5, pH 5-4
The pH's were adjusted to basic, if needed, and then sodium thiosulfate added.